AER Staff Beta Analysis June 2017

This paper was developed by the AER staff as part of their analysis of new evidence

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Executive Summary

This study is conducted to estimate the equity beta for the Australian Utilities comparator firms regulated by the AER. It has been conducted to provide an update of the estimated betas using the approach set in various studies conducted by Associate Professor Henry (formerly the University of Melbourne) for the Australian Energy Regulator (AER) (Henry (2014)) and extends the period of estimation to 30 April 2017.

Equity betas are estimated for four scenarios: (i) the longest possible period of data for the benchmark sample of nine Australian energy utility firms; (ii) the longest possible period of data for the benchmark sample after the tech boom (3 Jul 1998 to 30 October 2001) and *excluding* the GFC (5 September 2008 to 30 October 2009); and (iii) the most recent five years of data to 30 April 2017. Analyses are conducted at the individual firm and portfolio levels. Both equally weighted and value weighted averages are employed at the portfolio level.

Key findings from this study can be summarised as follows. *First,* at the individual firm level, across all methods and scenarios, the median value of estimated beta is 0.5424 whereas the mean value is 0.5754 which falls within the range of 0.2705 for DUET and 1.3022 for HDF. However, more than 50 per cent estimated beta is less than 0.6. *Second,* at the portfolio level, across various scenarios and portfolios, the mean value of the estimated beta for portfolios is approximately 0.5744 which varies within the range of 0.3509 (LAD estimates on Scenario 1) and 0.8118 (OLS estimates on Scenario 3). The median value for the estimated betas across various scenarios and portfolios is 0.5741 which is very close with the average value of 0.5744. However, it is noted that most of the estimates are clustered around 0.6. More than two thirds of the estimates are below 0.6. *Third,* there is no strong evidence of thin trading in this analysis at both individual firm and portfolio levels and as such the estimated betas from this study are robust and can be used for the regulatory purpose. *Fourth,* no sensible evidence of a structural break in the estimates of beta is found at both individual firm and portfolio levels. There is no theoretical justification for any “break” found on the empirical ground. As a result, the two-step approach should be considered for any possible break of the estimates of equity beta. *Fifth,* a stability test of the estimated beta parameter reveals that there is no strong evidence to support instability and therefore a range of 0.4 to 0.7 adopted by the AER is supported. Evidence still supports the above range of 0.4 – 0.7.

Estimates of equity beta across scenarios, methods and portfolios from this study can be presented in the following summaries.

Table 1: A Summary of Re-levered Betas at the individual firm level

Firm		AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
Scenario 1										
	OLS	0.8301	0.6858	0.7222	0.3416	0.3722	0.3503	1.3022	0.3913	0.3990
	LAD	0.6390	0.7060	0.7315	0.2705	0.3163	0.2786	0.7742	0.4418	0.5211
Scenario 2										
	OLS	0.9467	0.7062	0.7852	0.3768	0.3606	0.3534	0.9271	0.4141	0.5608
	LAD	0.6944	0.5065	0.7275	0.2979	0.3020	0.2786	0.7111	0.5467	0.5729
Scenario 3										
	OLS			0.9342	0.3094				0.4840	0.7893
	LAD			0.9440	0.3863				0.5380	0.7920

Source: the AER's analysis

Table 2: A Summary of Re-levered Beta at the portfolio level

			Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
Scenario 1								
	Equal							
		OLS	0.5669	0.5189	0.6059	0.5742	0.4680	0.4691
		LAD	0.5791	0.3910	0.5546	0.5558	0.5143	0.5536
	Value							
		OLS	0.5801	0.5287	0.5287	0.5098	0.4744	0.4886
		LAD	0.5607	0.3509	0.4916	0.5163	0.5158	0.5633
Scenario 2								
	Equal							
		OLS	0.5935	0.5226	0.6050	0.5841	0.5217	0.5472
		LAD	0.6018	0.3939	0.5760	0.6059	0.5884	0.6234
	Value							
		OLS	0.6210	0.5304	0.5984	0.5797	0.5479	0.5740
		LAD	0.5557	0.3535	0.5453	0.6100	0.5844	0.6109
Scenario 3								
	Equal							
		OLS	0.8076				0.5954	0.6136
		LAD	0.8094				0.6493	0.7327
	Value							
		OLS	0.8118				0.6344	0.6482
		LAD	0.7956				0.7099	0.7222

Source: the AER's analysis

On balance, when each of the above estimates is considered independently, two thirds of the above estimates are less than 0.6. In addition, the mean and median values of the estimated betas across scenarios, methods, and portfolios are also less than 0.6.

The structure of this study is as follows. Following this Introduction, Section 1 presents a summary of CEG's and Frontier Economics' estimates of equity beta in 2016. Both CEG and Frontier Economics studies have provided findings to support their argument that the estimated beta of more than 0.7 should be adopted in the AER's regulatory decisions in the future. Section 2 presents Henry/AER's study of equity beta in 2014 which sets the background for this study. The AER's 2017 study is discussed in Section 3 including the framework of estimating beta using market prices of individual stocks and stocks' portfolios;

Scenarios, estimates and tests; and the estimates of gearing. Empirical results are presented in Section 4. Replication of Henry (2014) study and CEG's 2016 study for comparison is discussed in Section 5. An analysis of a structural break in the estimates of equity beta is discussed in Section 6, followed by some concluding remarks in Section 7.

1. Latest empirical analyses on equity beta in Australia

Two of the latest analyses on equity beta were conducted by CEG in November 2016 and Frontier Economics in 2016. Each of these two studies is discussed in turn below.

1.1. CEG's analysis on equity beta

In its report prepared for Multinet prepared in November 2016, Competition Economists Group (CEG) has replicated and extended Henry (2014) study[1] to include data of the daily closing stock price, market capitalisation and net debt value of nine Australian stocks[2] (including *Alinta; the APA Group; Australian Gas Light; the DUET Group; Envestra; GasNet Australia Group; Hastings Diversified Utilities Fund; SP AusNet; and Spark Infrastructure)* up until 7 October 2016.

In relation to the estimates of the OLS weekly individual beta, CEG (2016)'s extended study indicates that the average re-levered equity beta has increased materially by 0.23 using the most recent five years of data ending on 7 October 2016.[3] CEG considers that this increase of equity beta reflects a number of factors including an increase/decrease in the raw equity betas/gearing ratios of the remaining four listed stocks (APA, DUE, SKI, AST) and an increase in the weighting of high-beta stocks (e.g., APA) in the value-weighted portfolios.

When all three sampling periods are considered including (i) longest available period; (ii) longest available period (excluding tech boom and GFC); and (iii) the latest 5 years, CEG is of the view that evidence suggests that beta has increased around 0.10 or more since the end of Henry's sampling period.[4]

In addition, in relation to the six portfolios for the two sampling periods (being longest available period; and longest available period excluding tech boom and GFC), CEG's findings indicate that beta has increased by around 0.15 or more.[5] For the most recent 5 year beta estimates for portfolios, CEG considers that the re-levered equity beta has

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1 Henry's analysis includes data up until 28 June 2013.

2 The Australian Energy Regulator, 2009, *Electricity transmission and distribution network service providers (NSP) on a review of the weighted average cost of capital (WACC) parameters, Final Decision*, May 2009, page 255.

3 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 1.

4 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 1.

5 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 2.

increased by 0.19 to 0.31 between the two periods in comparison with estimates from Henry (2014) study.[6]

In relation to the effect of sample size for value weighted portfolio, CEG has conducted analysis for various sample sizes including 1-year beta; 2-year beta; 3-year beta; 4-year beta; 5-year beta; and the longest sample. CEG's findings indicate that irrespective of the length of the sample period, the re-levered equity betas for samples ending in October 2016 are materially higher compared to the sample ending on Henry's sample end date.[7]

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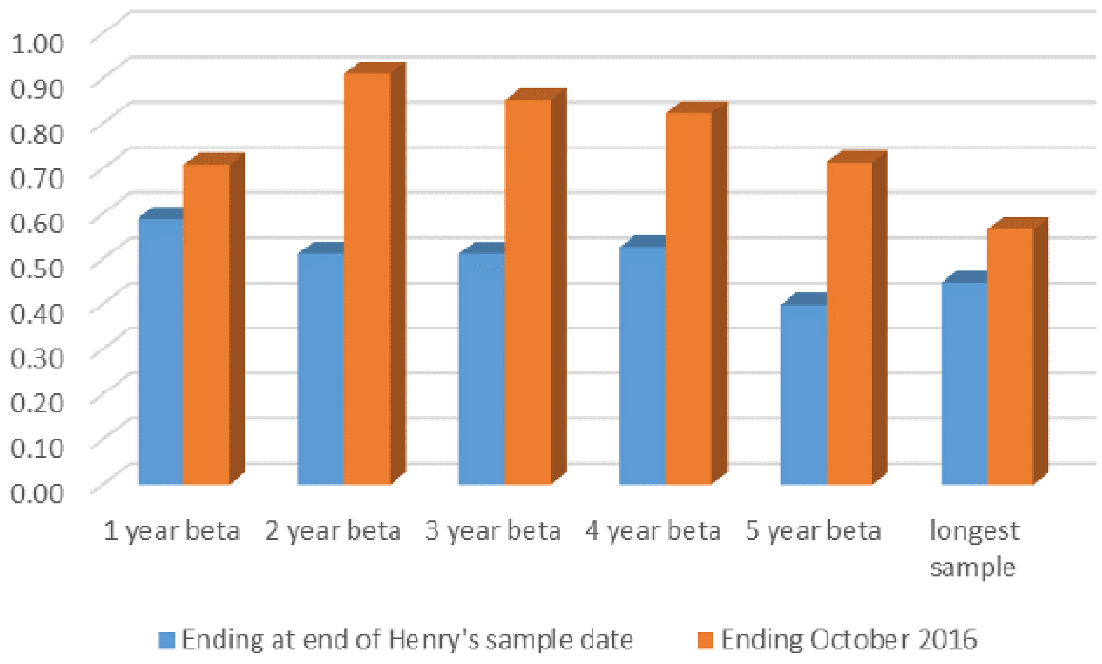
6 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 3.

7 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 4.

Figure 1: CEG's findings on the effect of sample size (Value weighted portfolio)



Source: CEG (November 2016)'s study, Figure 1, page 4.

With a particular emphasis, CEG conducted the Quandt-Andrews structural break test to determine whether the change in asset beta represents a statistically significant structural break. Portfolio 6, which is constructed to include APA AU Equity, DUE AU Equity, AST AU Equity, SKI AU Equity, is used for this test.[8] CEG argues that the Quandt-Andrews structural break test identifies a break within the GFC and, when run on post GFC data, identifies another break in August 2014.[9] On the basis of this "break", CEG is of the view that estimate of beta is not stable across the whole sample.

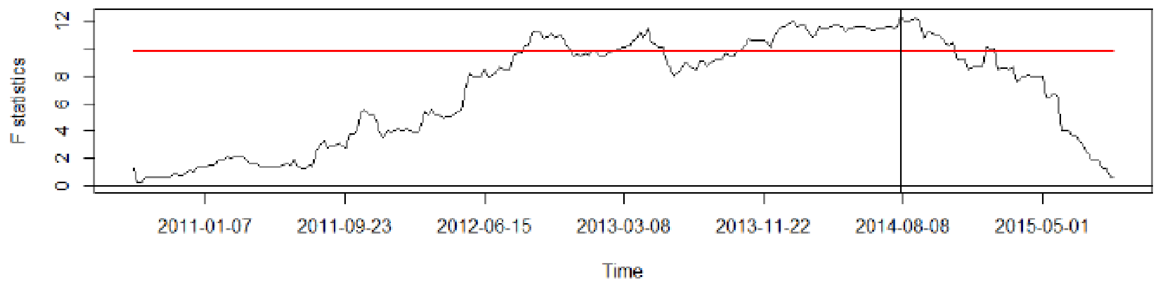
CEG then conducted the estimates of the re-levered equity beta before and after the August 2014 break point. CEG concludes that, for the equal (value) weighted portfolio 6, estimates of equity beta has increased by 0.38 (0.37) between the pre and post structural break sample periods. The best estimate of the re-levered equity beta is at least 0.88 after the 2014 August breakpoint and 0.7 over the last 5 years.[10]

8 It is noted that Portfolio 6 is the only portfolio for which all of the constituents have data to October 2016.

9 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 4.

10 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 5.

Figure 2: CEG (2016)'s F-statistics for value weighted portfolio (post GFC)



Source: CEG (November 2016)'s study, Figure 2, page 5.

CEG considers that, as presented in Figure 2 above, the high F-statistics from late 2012 to late 2014 suggests that discernible differences in asset beta began presenting in the data up-to two years prior to the maximum F-statistic observed for August 2014. As a result, CEG is of the view that it is reasonable to have regard to 3 and 4 year beta estimates when a post-break asset beta estimate is attempted.[11] CEG's estimates indicate that, based on 3-4 year period, beta estimates fall within the range of 0.83 and 0.79 (equal weighted average) [12] and of 0.85 and 0.82 (value weighted average).[13] CEG contends that these estimates support a post-structural break estimate for the re-levered equity beta of 0.8 (based on 3-4 year betas) to 0.9 (based on the identified date of the highest F-statistic).[14]

1.2. Frontier Economics' analysis on equity beta in December 2016

In a report prepared for APA Group, Frontier Economics (Frontier) provided its view on the AER's approach to estimating the equity beta for use in the Sharpe-Lintner Capital Asset Pricing Model (SL-CAPM). Frontier's analysis is conducted on two different data samples. First, the AER's sample includes only the remaining four domestic regulated utility comparator firms with available data until 2016 (APA Group, AusNet Services, DUET and Spark Infrastructure). Second, an extended sample includes a broader set of firms that have investments in long-lived infrastructure assets. Data used in Frontier's analysis covers the period of 10 years, from 01 September 2006 to 01 September 2016.[15]

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11 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 5.

12 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, Table 16, page 19.

13 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, Table 17, page 20.

14 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 5.

15 Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses, a report prepared for APA Group*, December 2016, page 14.

Findings from Frontier's analysis with regards to the sample of 4 firms can be summarised as follows.

- In relation to the estimates for individual betas using weekly data, Frontier concluded that the re-levered equity beta estimates for three of the four firms are in the order of 0.7 to 0.8, with the DUET estimate appearing to be an outlier in the sense that it is materially below the other three estimates. Frontier's findings indicate that the mean estimate over the four firms is 0.63, and if DUET is excluded the mean rises to 0.75.[16]
- In relation to portfolio estimates of beta using weekly data, Frontier's analysis indicates that the value- and equally-weighted portfolio estimates are 0.65 and 0.72.[17]
- The monthly estimates are generally higher than the weekly estimates.[18]
- The 10-year estimates are generally lower than the 5-year estimates.[19]
- When the rolling beta estimates are conducted, Frontier concludes that there is an obvious increase in the portfolio beta estimates as data from 2014, 2015 and 2016 is introduced, replacing older data from 2006-2008.[20]

When the sample is extended to include another 6 unregulated infrastructure firms (including Auckland International Airport; Aurizon; Macquarie Atlas Roads; Qube Logistics; Sydney Airport; and Transurban), the estimates of beta at the individual firm level are materially higher, from 1.11 to 1.29.[21] The re-levered equity beta estimates are 0.98 and 0.79 for the equally-weighted and value-weighted portfolios, respectively.[22]

Frontier concludes that the analysis of unregulated infrastructure firms is that the re-levered equity beta estimates are all materially above the AER's current starting-point "best

[16] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 16.

[17] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 16.

[18] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 17.

[19] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 19.

[20] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 19.

[21] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 22.

[22] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 23.

statistical" equity beta estimate. As such, Frontier is of the view that if this evidence were to be afforded any weight, the result would be an increase in the equity beta allowance.[23]

2. The AER/Henry's estimates of equity beta in 2014

In its WACC Review in 2009, the AER adopted the estimate of equity beta of 0.8 on the ground of an empirical study conducted by Associate Professor Henry at the University of Melbourne. Henry, currently at the University of Liverpool in the UK, was retained to provide an advice to the AER in April 2014. Key findings from this latest study for the AER can be summarised as below.[24]

- The use of data sample at a weekly frequency is recommended.
- Continuously compounded returns are used. There was no evidence that β estimates obtained from discretely compounded data are manifestly different. In addition, the use of raw as opposed to excess returns is recommended.
- There is no overwhelming issue with instability of beta estimates.
- In terms of the sample period, Henry is of the view that the most appropriate approach is to use all available data. Henry also considers that to omit data because of concerns about instability is only correct where there is strong evidence of instability and that, in his 2014 study, there is little evidence of instability in the intercept or slope of the Security Market Line estimated using the full sample.
- Henry is of the view that the most reliable evidence about the magnitude of β is derived from the estimates of betas using individual assets and fixed weight portfolios. Henry also considers that the "time-varying portfolios" are not well grounded in financial theory.
- Henry advises that the majority of the evidence presented in his 2009 report, across all estimators, firms and portfolios, and all sample periods considered, suggests that the point estimate for β lies in the range 0.3 to 0.8.

This study is conducted by the AER in May 2017 (with the data up to 30 April 2017) on the basis of Henry's previous advices. In this study, analyses are conducted in two scenarios: (i) Individual firm analysis; and (ii) Portfolio analysis using fixed weight portfolios (including Equal weighted average and Value weighted average). In addition, various tests are also conducted such as thin trading analysis (for both scenarios: individual firms and fixed weight

[23] Frontier Economics, 2016, *An equity beta estimate for Australian energy network businesses*, a report prepared for APA Group, December 2016, page 24.

[24] Henry, T. O. 2014, *Estimating Beta: An Update*, a report prepared for the Australian Energy Regulator, April 2014, pp. 62-63.

portfolios) and stability and sensitivity analysis (for both scenarios). In particular, this study conducts tests for structural breaks to check for evidence of high equity beta since Henry's study in 2014.

The benchmark sample used in this study is the same with those adopted by Henry (2009; 2014) and CEG's study (2016). However, data of the daily closing stock price, market capitalisation and net debt value are extended to 30 April 2017. The summary of the considered periods is as below.

Table 3: Sampling period: AER's (2017) study versus Henry (2014) study and CEG (November 2016) study

Company	Bloomberg Ticker	Starting Date	Ending Date (when difference otherwise blank)			No. of Observations			Difference in No. of Observations	
			Henry (2014)	CEG (Nov 2016)	AER (May 2017)	Henry (2014)	CEG (Nov 2016)	AER (May 2017)	AER vs. Henry	AER vs. CEG
Alinta	AAN AU Equity	20/10/2000	28/06/2013			356	356	356	0	0
Australian Gas Light	AGL AU Equity	29/5/1992	6/10/2006			749	749	749	0	0
The APA Group	APA AU Equity	16/6/2000	28/06/2013	7/10/2016	30/4/2017	680	851	880	200	29
The DUET Group	DUE AU Equity	13/8/2004	28/06/2013	7/10/2016	30/4/2017	463	634	663	200	29
Envestra	ENV AU Equity	29/8/1997	28/06/2013	12/9/2014		826	889	889	63	0
GasNet Australia Group	Gas AU Equity	21/12/2001	10/11/2006			255	255	255	0	0
Hastings Diversified Utilities Fund	HDF AU Equity	17/12/2004	23/11/2012			414	414	414	0	0
Spark Infrastructure	SKI AU Equity	02/03/2007	28/06/2013	7/10/2016	30/4/2017	330	501	530	200	29
SP AusNet	AST AU Equity	16/12/2005	28/06/2013	7/10/2016	30/4/2017	393	564	593	200	29

Source: Bloomberg Data; CEG (2016), AER analysis

3. The AER's analysis of equity beta in 2017

3.1. The framework of estimating beta using market prices of individual stocks and stocks' portfolios

The equity beta is a key input parameter in the Sharpe–Lintner Capital Asset Pricing Model (CAPM). Equity beta measures the sensitivity of an asset or business's returns to movements in the overall market returns (systematic or market risk).[25] The CAPM predicts that the expected return to the asset *i* is estimated by:

$$r_{i,t} = \alpha_i + \beta_i r_{mt} + \varepsilon_{i,t} \qquad (1)$$

in which, the residual is $\varepsilon_{i,t} = r_{i,t} - \alpha_i - \beta_i r_{mt}$

The continuously compounded raw return to asset *i* can be calculated as:

$$r_{i,t} = \ln(P_{it}/P_{it-1})$$

The price of asset i has been adjusted for the payment of dividends. As such, this price represents a measure of total return to the investor. In addition, a return to the market, where A is the ASX300 accumulation index, can be defined as below:

$$r_{Mt} = \ln(A_{it}/A_{it-1})$$

In 2009, Associate Professor Henry from the University of Melbourne, Australia established his work in estimating equity beta for the Australian Utilities regulation as an advice to the Australian Competition and Consumer Commission (Henry, 2009). Five years later, Henry and Street (2014) updated the estimates. In these two studies, the Ordinary Least Squares (OLS) and Least Absolute Deviations (LAD) approaches are utilized.[26]

3.2. Ordinary Least Squares

The OLS method estimates the α_i and β_i in the equation (1) by minimizing the sum of squared residuals:

$$\sum_{t=1}^{T} \varepsilon_{i,t}^2 = \sum_{t=1}^{T} (r_{i,t} - \hat{r}_{i,t})^2 = \sum_{t=1}^{T} (r_{i,t} - \hat{\alpha}_i - \hat{\beta} r_{m,t})^2$$

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25 McKenzie and Partington, *Risk, asset pricing models and WACC*, June 2013, p. 21; Brealey, Myers, Partington, Robinson, *Principles of Corporate Finance*, McGraw-Hill Australia: First Australian Edition, 2000, p. 187.

26 Vo et al. (2014) re-examined the estimates of beta in the Australian regulatory context. In their study, a data set was updated in comparison with Henry's study in 2009. In addition, another key contribution from Vo et al. (2014) study was that two new approaches were added in their study: (i) the Maximum Likelihood robust theory (MM) and (ii) the Theil Sen methodology. For each of these new approaches, the authors argued that among the robust regression estimators currently available, the MM regression had the highest breakdown point (50 percent) and high statistical efficiency (95 percent) while the Theil Sen estimator was proposed by Fabozzi (2013) in response to the OLS estimator being acutely sensitive to outliers. Further details, see Vo, D. et. al. (2014*) Equity Beta for the Australian Utilities* is well below 1.0, a paper presented at the Australasian Econometric Society Conference, Hobart, 2014.

The β coefficient from OLS indicates the average relationship between the regressor and the outcome variable based on the conditional mean function.

3.3. Least Absolute Deviations

In the LAD approach, the absolute value of residuals is minimized to achieve the estimates from equation (1) as follows:

$$\sum_{t=1}^{T}|\varepsilon_{i,t}| = \sum_{t=1}^{T}|r_{i,t} - \hat{r}_{i,t}| = \sum_{t=1}^{T}|r_{i,t} - \hat{\alpha}_i - \hat{\beta} r_{m,t}|$$

Since the sum of the absolute value of residuals is minimized rather than minimizing the sum of squares, the estimators obtained from the LAD method may alleviate the effect of outliers.

3.4. De-levered/Re-levered

Supposing that the debt β equals to zero, the de-levering/re-levering equation is:

$$\beta_A = \beta_E \frac{E}{V}$$

In which β_A and β_E are the asset β and equity β; E/V is the ratio between the market value of equity and the company's total asset. The gearing ratio is usually defined as the proportion of the book value of debt in the value of the company that is measured by its total asset. Considering $\bar{G}$ as the gearing ratio, $\bar{D}$ as the book value of debt and E is the market value of equity, then:

$$\bar{G} = \frac{\bar{D}}{\bar{D} + E}$$

For the estimation of re-levered beta, the following re-levering factor is applied to the estimates of raw beta, with the assumed benchmark gearing of 60 per cent:

$$\omega = \frac{1 - \bar{G}}{1 - 0.6}$$

In addition, the following tests including: (i) thin trading; (ii) stability and sensitivity analysis; and (iii) structural break test are conducted to ensure that estimates of beta using historical data on stocks and market returns are appropriate for the purpose of regulation. Each of these tests is discussed in turn below.

3.5. Thin trading

Henry (2016) considered that thin trading can create issues with the magnitude of the estimate of β. In effect, he considered that if the stock does not trade regularly, the OLS estimate of β tends to be biased towards zero. Henry used the Dimson approach to calculate the Dimson adjustment which involves estimation of the following regression:

$$r_{i,t} = \alpha_i + \beta_{i-1} r_{m,t-1} + \beta_i r_{m,t} + \beta_{i+1} r_{m,t+1} + \varepsilon_{it}$$

3.6. Stability and sensitivity analysis

In Henry's 2014 analysis, two approaches were implemented that specifically assess the structural stability of the regressions: (i) recursive least square estimates including two approaches, an expanding window of observations and a fixed window that is rolled across the sample, and (ii) Hansen's test for parameter stability.

3.7. Structural break test

In its 2016 analysis, CEG employed the Quandt-Andrews test to test a structural break in the estimate of beta.

3.8. Scenarios, Estimates and Tests

In this study, various scenarios are considered under different periods of data. The following time periods are considered.

Scenario 1: The longest possible period of data for each firm in the sample as presented in Table 3.

Scenario 2: The longest possible period of data for each firm in the sample after the tech boom (from 3 July 1998 to 28 December 2001) and the GFC (from 5 September 2008 to 30 October 2009).

Scenario 3: The most recent 5 years of data ending on 30 April 2017.

For each of the above scenario, the following analyses are conducted:

- Estimates of equity beta for individual firms;
- Estimates of equity beta for portfolios using fixed weight[27] including: (i) Equal weighted average; and (ii) Value weighted average.
- Analysis of thin trading;

[27] Varying weighted approach is not utilised in this study on the ground of Henry (2014) study. Henry considered that great caution should be exercised when interpreting the β estimates from the resulting 'time-varying portfolios' as they are not grounded in financial theory (Henry 2014, page 52).

- Analysis of stability and sensitivity of the estimates; and
- Analysis of a structural break.

In addition, to facilitate a comparison of the findings from this study and those from Henry (2014) study and CEG's analysis, replications of empirical results using data from this study to compare results with Henry (2014);[28] and CEG (November 2016)[29] with the same ending data for each relevant study.[30]

3.9. Estimates of Gearing

The re-levered beta is adopted in the estimate of a return on equity using the Sharpe Lintner CAPM in the AER's regulatory decisions. As previously discussed, prior to the estimate of this re-levered beta using the benchmark gearing of 60 per cent Debt over Total Asset, raw beta obtained from the empirical analysis must be de-levered using the actual gearing level for each firm in the benchmark sample.

In his analysis, Henry stated that the level of gearing is usually defined as the book value of debt divided by the value of the firm as represented by the sum of the market value of equity and the book value of debt.[31] Henry noted that the average gearing level is calculated for the sample period using data obtained from Bloomberg.[32] In addition, in their report, CEG indicated that gearing is calculated based on the average market capitalisation and net debt during the sampling period.[33]

In this analysis, a gearing of firms in the benchmark sample is estimated using data of "Total Debt to Total Capitalisation" from Bloomberg which can be expressed as below:[34]

$$\text{Gearing} = \frac{\textit{Total Debt to Total Capitalisation}}{1 + \text{ Total Debt to Total Capitalisation}}$$

4. Empirical results

Each of the above analyses associated with each scenario, as presented in Section 3 above, will be discussed in turn below.

28 Henry, T. O. 2014, *Estimating Beta: An Update*, a report prepared for the Australian Energy Regulator, April 2014.

29 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016.

30 28 June 2013 is the ending data for Henry (2014) study whereas 6 October 2017 and 1 September 2016 are the ending dates for CEG (Nov 2016) and Frontier Economics (2016) studies respectively.

31 Henry, T. O. 2014, *Estimating Beta: An Update*, a report prepared for the Australian Energy Regulator, April 2014, pp.12-13.

32 Henry, T. O. 2014, *Estimating Beta: An Update*, a report prepared for the Australian Energy Regulator, April 2014, page 12.

33 Competition Economists Group, 2016, *Replication and extension of Henry's beta analysis*, November 2016, page 8.

34 With the exception for SKI's gearing which is adjusted using data from their relevant annual reports.

4.1. The analysis of individual firms

In this study, estimates of beta are conducted at both the individual and portfolio levels. This section provides the estimated betas for 9 firms in the benchmark sample under various scenarios as previously discussed, including: (i) the longest possible period of data for each firm in the sample; (ii) the longest possible period of data for each firm in the sample after the tech boom (from 3 July 1998 to 28 December 2001) and the GFC (from 5 September 2008 to 30 October 2009); and (iii) the most recent 5 years of data ending on 30 April 2017.

4.1.1. Estimation results of re-levered beta

Empirical findings presented in Table 4 to Table 7 indicate a wide range of estimated betas using both OLS and LAD. These tables present the estimates of betas including both raw betas and de-levered/re-levered betas. Across all methods and scenarios, the highest estimate of 1.30 is for HDF and the lowest estimate of 0.27 is for DUET. The mean value of estimated beta is 0.58 whereas the median is 0.55. It is noted that more than 50 per cent of the estimates are lower than the mean estimated value.

Table 4: Scenario 1 - The longest possible period of data for each firm in the sample

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
Start	20/10/2000	29/05/1992	16/06/2000	13/08/2004	29/08/1997	21/12/2001	17/12/2004	2/03/2007	16/12/2005
End	17/08/2007	6/10/2006	28/04/2017	28/04/2017	12/09/2014	10/11/2006	23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.5426**	**0.4076**	**0.6066**	**0.4656**	**0.4892**	**0.3928**	**0.9478**	**0.4252**	**0.3942**
S.e	0.1103	0.0643	0.0459	0.0639	0.0716	0.1169	0.1392	0.0646	0.0576
Upper	0.7588	0.5336	0.6966	0.5908	0.6295	0.6219	1.2206	0.5518	0.5071
Lower	0.3264	0.2816	0.5166	0.3404	0.3489	0.1637	0.6750	0.2986	0.2813
LAD Beta	**0.4177**	**0.4196**	**0.6144**	**0.3688**	**0.4158**	**0.3124**	**0.5635**	**0.4801**	**0.5149**
S.e	0.1056	0.0667	0.0451	0.0481	0.0432	0.1133	0.0586	0.0619	0.0544
Upper	0.6247	0.5503	0.7028	0.4631	0.5005	0.5345	0.6784	0.6014	0.6215
Lower	0.2107	0.2889	0.5260	0.2745	0.3311	0.0903	0.4486	0.3588	0.4083
N	356	749	880	663	889	255	414	530	593
R^2	0.064	0.0511	0.166	0.0743	0.05	0.0427	0.1012	0.0759	0.0736
Gearing	0.3880	0.3270	0.5237	0.7066	0.6957	0.6433	0.4504	0.6319	0.5952
W	1.5299	1.6826	1.1906	0.7336	0.7607	0.8918	1.3740	0.9202	1.0121
OLS Re-levered Beta	**0.8301**	**0.6858**	**0.7222**	**0.3416**	**0.3722**	**0.3503**	**1.3022**	**0.3913**	**0.3990**
S.e	0.1103	0.0643	0.0459	0.0639	0.0716	0.1169	0.1392	0.0646	0.0576
Upper	1.0463	0.8119	0.8122	0.4668	0.5125	0.5794	1.5751	0.5179	0.5119
Lower	0.6139	0.5598	0.6323	0.2163	0.2318	0.1212	1.0294	0.2647	0.2861
LAD Re-levered Beta	**0.6390**	**0.7060**	**0.7315**	**0.2705**	**0.3163**	**0.2786**	**0.7742**	**0.4418**	**0.5211**
S.e	0.1056	0.0667	0.0451	0.0481	0.0432	0.1133	0.0586	0.0619	0.0544
Upper	0.8460	0.8368	0.8199	0.3648	0.4010	0.5007	0.8891	0.5631	0.6278
Lower	0.4321	0.5753	0.6431	0.1763	0.2316	0.0565	0.6594	0.3205	0.4145

Table 5: Scenario 2 - The longest possible period of data for each firm after *the tech boom* & excluding *the GFC*

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
Start - After Techboom	4/01/2002	4/01/2002	4/01/2002	13/08/2004	4/01/2002	4/01/2002	17/12/2004	2/03/2007	16/12/2005
End	17/08/2007	6/10/2006	29/08/2008	29/08/2008	29/08/2008	10/11/2006	29/08/2008	29/08/2008	29/08/2008
Start - After GFC			6/11/2009	6/11/2009	6/11/2009		6/11/2009	6/11/2009	6/11/2009
End			28/04/2017	28/04/2017	12/09/2014		23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.6188**	**0.4197**	**0.6464**	**0.4973**	**0.4611**	**0.3963**	**0.6786**	**0.4386**	**0.5433**
S.e	0.1288	0.0977	0.0542	0.0664	0.0618	0.1172	0.0867	0.0739	0.0600
Upper	0.8712	0.6112	0.7526	0.6274	0.5822	0.6260	0.8485	0.5834	0.6609
Lower	0.3664	0.2282	0.5402	0.3672	0.3400	0.1666	0.5087	0.2938	0.4257
LAD Beta	**0.4539**	**0.301**	**0.5989**	**0.3932**	**0.3862**	**0.3124**	**0.5205**	**0.5791**	**0.555**
S.e	0.1232	0.1150	0.0564	0.0578	0.0554	0.1129	0.0689	0.0745	0.0623
Upper	0.6954	0.5264	0.7094	0.5065	0.4948	0.5337	0.6555	0.7251	0.6771
Lower	0.2124	0.0756	0.4884	0.2799	0.2776	0.0911	0.3855	0.4331	0.4329
N	294	249	739	602	602	254	353	469	532
R^2	0.0733	0.0695	0.1618	0.0854	0.0848	0.0434	0.1485	0.0701	0.1338
Gearing	0.3880	0.3270	0.5141	0.6969	0.6872	0.6433	0.4535	0.6224	0.5871
W	1.5299	1.6826	1.2148	0.7577	0.7821	0.8918	1.3662	0.9440	1.0322
OLS Re-levered Beta	**0.9467**	**0.7062**	**0.7852**	**0.3768**	**0.3606**	**0.3534**	**0.9271**	**0.4141**	**0.5608**
S.e	0.1288	0.0977	0.0542	0.0664	0.0618	0.1172	0.0867	0.0739	0.0600
Upper	1.1992	0.8977	0.8915	0.5070	0.4817	0.5831	1.0970	0.5589	0.6784
Lower	0.6943	0.5147	0.6790	0.2467	0.2395	0.1237	0.7571	0.2692	0.4432
LAD Re-levered Beta	**0.6944**	**0.5065**	**0.7275**	**0.2979**	**0.3020**	**0.2786**	**0.7111**	**0.5467**	**0.5729**
S.e	0.1232	0.115	0.0564	0.0578	0.0554	0.1129	0.0689	0.0745	0.0623
Upper	0.9359	0.7319	0.8381	0.4112	0.4106	0.4999	0.8461	0.6927	0.6950
Lower	0.4530	0.2811	0.6170	0.1847	0.1934	0.0573	0.5760	0.4007	0.4507

Table 6: Scenario 3 - The most recent 5 years of data ending on 30 April 2017

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
Start - After GFC			4/05/2012	4/05/2012				4/05/2012	4/05/2012
End			28/04/2017	28/04/2017				28/04/2017	28/04/2017
OLS Beta			**0.6689**	**0.3061**				**0.4762**	**0.7227**
S.e			0.0841	0.1033				0.0941	0.0905
Upper			0.8337	0.5086				0.6606	0.9001
Lower			0.5041	0.1036				0.2918	0.5453
LAD Beta			**0.6759**	**0.3821**				**0.5293**	**0.7252**
S.e			0.1044	0.0775				0.1093	0.0895
Upper			0.8805	0.5340				0.7435	0.9006
Lower			0.4713	0.2302				0.3151	0.5498
N			261	261				261	261
R^2			0.1963	0.0328				0.09	0.1976
Gearing			0.4413	0.5956				0.5934	0.5632
W			1.3967	1.0109				1.0165	1.0921
OLS Re-levered Beta			**0.9342**	**0.3094**				**0.4840**	**0.7893**
S.e			0.0841	0.1033				0.0941	0.0905
Upper			1.0991	0.5119				0.6685	0.9666
Lower			0.7694	0.1070				0.2996	0.6119
LAD Re-levered Beta			**0.9440**	**0.3863**				**0.5380**	**0.7920**
S.e			0.1044	0.0775				0.1093	0.0895
Upper			1.1486	0.5382				0.7522	0.9674
Lower			0.7394	0.2344				0.3238	0.6166

4.1.2. Analysis of thin trading

With regard to thin trading, as presented in Table 7 to Table 9, there is no evidence of thin trading in this study. This finding is consistent with Henry's findings in his 2014 study.

Table 7: Scenario 1 - The longest possible period of data for each firm in the sample

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
β_{i-1}	-0.0891	-0.0362	0.0218	0.1436	0.0298	-0.0903	0.1192	0.0954	0.0537
S.E	0.1130	0.0646	0.0458	0.0640	0.0718	0.1179	0.1401	0.0646	0.0576
β_i	0.5529	0.4071	0.6026	0.4703	0.4886	0.4103	0.9552	0.4279	0.3903
S.E	0.1129	0.0645	0.0459	0.0640	0.0718	0.1182	0.1400	0.0646	0.0577
β_{i+1}	0.0742	0.0052	-0.1131	-0.0358	-0.0472	-0.1029	0.0551	0.0057	-0.0638
S.E	0.1111	0.0645	0.0459	0.0640	0.0718	0.1180	0.1399	0.0646	0.0576
β^{D}_{i}	0.5380	0.3761	0.5113	0.5781	0.4712	0.2171	1.1295	0.5290	0.3802
S.E									
β^{OLS}_{i}	0.5426	0.4076	0.6066	0.4656	0.4892	0.3928	0.9478	0.4252	0.3942
S.E	0.1103	0.0643	0.0459	0.0639	0.0716	0.1169	0.1392	0.0646	0.0576
$\beta^{OLS}_{i} = \beta^{D}_{i}$	0.0417	0.4899	2.0763	-1.7606	0.2514	1.5030	-1.3053	-1.6068	0.2431
N	354	747	878	661	887	253	412	528	591

Table 8: Scenario 2 - The longest possible period of data for each firm after *the tech boom* & excluding *the GFC*

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
β_{i-1}	-0.1459	-0.0411	-0.0202	0.0178	0.0001	-0.0881	-0.0643	-0.0405	-0.0001
S.E	0.1337	0.0998	0.0543	0.0671	0.0622	0.1183	0.0881	0.0741	0.0604
β_i	0.6457	0.4244	0.6309	0.5012	0.4737	0.4103	0.6718	0.4487	0.5392
S.E	0.1332	0.0988	0.0543	0.0671	0.0622	0.1184	0.0879	0.0742	0.0604
β_{i+1}	-0.0137	-0.0671	-0.0511	0.0602	-0.0182	-0.1042	0.0085	0.0186	-0.0953
S.E	0.1300	0.0986	0.0542	0.0670	0.0620	0.1182	0.0875	0.0739	0.0602
β^D_i	0.4861	0.3162	0.5596	0.5792	0.4556	0.2180	0.6160	0.4268	0.4438
S.E									
β^{OLS}_i	0.6188	0.4197	0.6464	0.4973	0.4611	0.3963	0.6786	0.4386	0.5433
S.E	0.1288	0.0977	0.0542	0.0664	0.0618	0.1172	0.0867	0.0739	0.0600
$\beta^{OLS}_i = \beta^D_i$	1.0303	1.0594	1.6015	-1.2334	0.0890	1.5213	0.7220	0.1597	1.6583
N	292	247	735	598	598	252	349	465	528

Table 9: Scenario 3 - The most recent 5 years of data ending on 30 April 2017

	AAN	AGL	APA	DUE	ENV	GAS	HDF	SKI	AST
β_{i-1}			0.0723	0.0182				0.0255	0.1408
S.E			0.0834	0.1046				0.0944	0.0910
β_i			0.6631	0.3042				0.4667	0.7229
S.E			0.0833	0.1044				0.0943	0.0909
β_{i+1}			-0.2067	-0.0644				-0.1659	-0.1280
S.E			0.0838	0.1050				0.0948	0.0913
β^D_i			0.5287	0.2580				0.3263	0.7357
S.E									
β^{OLS}_i			0.6689	0.3061				0.4762	0.7227
S.E			0.0841	0.1033				0.0941	0.0905
$\beta^{OLS}_i = \beta^D_i$			1.6671	0.4656				1.5930	-0.1436
N			259	259				259	259

4.1.3. Analysis of Stability and Sensitivity

In Henry's (2014) analysis, two approaches were implemented that specifically assess the structural stability of the regressions: recursive least square estimates (including the two main approaches: (i) an expanding window of observations; and (ii) a fixed window that is rolled across the sample) and Hansen's test for parameter stability.[35]

Appendix 1 presents the results from this study. The results indicate that there is no evidence to support the view that the recursive estimation conducted in this study provides systematic or strong evidence of parameter instability in both OLS and LAD estimates of beta for individual firms.

4.2. The analysis of portfolios using fixed weight

Portfolios are formed for the purpose of this study. The first 5 portfolios, from P1 to P5, are from Henry's studies (2009 and 2014) whereas Portfolio 6 has been recently added in the CEG's study (2016). It is noted that Portfolio 6 includes only 4 firms which are still on trading as at April 2017. Estimation results together with various tests are presented below.

4.2.1. Estimation results of re-levered beta

Two different weighted averages are considered in the analysis of portfolios using fixed weight. Each of these averages is presented in turn below.

Equally weighted average

The following tables, from Table 10 to Table 15, present the estimated betas for portfolios under two scenarios: (i) the longest possible period of data for each firm in the benchmark sample; (ii) the longest possible period of data excluding the tech boom and the GFC; and (iii) the most recent 5-years period. It is noted that, as Henry's analysis (2014) indicated, the starting date for the portfolios are not the same with those for individual firm analyses.

[35] Henry, T. O. 2014, *Estimating Beta: An Update*, a report prepared for the Australian Energy Regulator, April 2014, page 14.

Table 10: Scenario 1 - The longest period of data for the portfolios

Portfolio	P1	P2	P3	P4	P5	P6
Firm	**APA, ENV**	**AAN, AGL, APA, ENV, GAS**	**APA, DUE, ENV, HDF, AST**	**APA, DUE, ENV, HDF, SKI, AST**	**APA, DUE, ENV, SKI, AST**	**APA, DUE, SKI, AST**
Start	16/06/2000	21/12/2001	16/12/2005	2/03/2007	2/03/2007	2/03/2007
End	28/04/2017	6/10/2006	23/11/2012	23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.5810**	**0.4284**	**0.5974**	**0.5750**	**0.5068**	**0.4865**
S.e	0.0441	0.0614	0.0575	0.0598	0.0408	0.0417
Upper	0.6674	0.5487	0.7101	0.6922	0.5868	0.5682
Lower	0.4946	0.3081	0.4847	0.4578	0.4268	0.4048
LAD Beta	**0.5935**	**0.3228**	**0.5468**	**0.5566**	**0.5569**	**0.5742**
S.e	0.0366	0.0747	0.0353	0.0388	0.033	0.0347
Upper	0.6652	0.4692	0.6160	0.6326	0.6216	0.6422
Lower	0.5218	0.1764	0.4776	0.4806	0.4922	0.5062
N	880	250	362	299	530	530
R^2	0.165	0.1642	0.2307	0.2371	0.2263	0.2046
Gearing	0.6097	0.5155	0.5943	0.6006	0.6306	0.6143
W	0.9757	1.2111	1.0142	0.9985	0.9235	0.9641
OLS Re-levered Beta	**0.5669**	**0.5189**	**0.6059**	**0.5742**	**0.4680**	**0.4691**
S.e	0.0441	0.0614	0.0575	0.0598	0.0408	0.0417
Upper	0.6533	0.6392	0.7186	0.6914	0.5480	0.5508
Lower	0.4804	0.3985	0.4932	0.4570	0.3880	0.3873
LAD Re-levered Beta	**0.5791**	**0.3910**	**0.5546**	**0.5558**	**0.5143**	**0.5536**
S.e	0.0366	0.0747	0.0353	0.0388	0.0330	0.0347
Upper	0.6508	0.5374	0.6238	0.6318	0.5790	0.6216
Lower	0.5073	0.2445	0.4854	0.4797	0.4496	0.4856

Table 11: Scenario 2 - The longest possible period of data for the portfolios excluding the tech boom and the GFC

	P1	P2	P3	P4	P5	P6
Firm	**APA, ENV**	**AAN, AGL, APA, ENV, GAS**	**APA, DUE, ENV, HDF, AST**	**APA, DUE, ENV, HDF, SKI, AST**	**APA, DUE, ENV, SKI, AST**	**APA, DUE, SKI, AST**
Start	4/01/2002	4/01/2002	16/12/2005	2/03/2007	2/03/2007	2/03/2007
End	28/04/2017	6/10/2006	23/11/2012	23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.5944**	**0.4283**	**0.5870**	**0.5748**	**0.5514**	**0.5543**
S.e	0.0426	0.0616	0.0493	0.0546	0.0407	0.0433
Upper	0.6779	0.5490	0.6836	0.6818	0.6312	0.6392
Lower	0.5109	0.3076	0.4904	0.4678	0.4716	0.4694
LAD Beta	**0.6027**	**0.3228**	**0.5589**	**0.5963**	**0.6219**	**0.6315**
S.e	0.0431	0.0769	0.0433	0.0488	0.0385	0.0402
Upper	0.6872	0.4735	0.6438	0.6919	0.6974	0.7103
Lower	0.5182	0.1721	0.4740	0.5007	0.5464	0.5527
N	739	249	301	238	469	469
R^2	0.209	0.1636	0.3213	0.3192	0.2817	0.26
Gearing	0.6006	0.5119	0.5878	0.5935	0.6215	0.6051
W	0.9984	1.2202	1.0306	1.0162	0.9462	0.9872
OLS Re-levered Beta	**0.5935**	**0.5226**	**0.6050**	**0.5841**	**0.5217**	**0.5472**
S.e	0.0426	0.0616	0.0493	0.0546	0.0407	0.0433
Upper	0.6770	0.6434	0.7016	0.6911	0.6015	0.6321
Lower	0.5100	0.4019	0.5083	0.4771	0.4419	0.4623
LAD Re-levered Beta	**0.6018**	**0.3939**	**0.5760**	**0.6059**	**0.5884**	**0.6234**
S.e	0.0431	0.0769	0.0433	0.0488	0.0385	0.0402
Upper	0.6862	0.5446	0.6609	0.7016	0.6639	0.7022
Lower	0.5173	0.2432	0.4911	0.5103	0.5130	0.5446

Table 12: Scenario 3 – The most recent 5 years

Firm	P1 APA, ENV	P2 AAN, AGL, APA, ENV, GAS	P3 APA, DUE, ENV, HDF, AST	P4 APA, DUE, ENV, HDF, SKI, AST	P5 APA, DUE, ENV, SKI, AST	P6 APA, DUE, SKI, AST
Start	4/05/2012				4/05/2012	4/05/2012
End	28/04/2017				28/04/2017	28/04/2017
OLS Beta	**0.6623**				**0.5356**	**0.5435**
S.e	0.0820				0.0613	0.0625
Upper	0.8230				0.6557	0.6660
Lower	0.5016				0.4155	0.4210
LAD Beta	**0.6638**				**0.5841**	**0.6490**
S.e	0.0823				0.0592	0.0665
Upper	0.8251				0.7001	0.7793
Lower	0.5025				0.4681	0.5187
N	261				261	261
R^2	0.201				0.2278	0.226
Gearing	0.5123				0.5554	0.5484
W	1.2193				1.1116	1.1290
OLS Re-levered Beta	**0.8076**				**0.5954**	**0.6136**
S.e	0.0820				0.0613	0.0625
Upper	0.9683				0.7155	0.7361
Lower	0.6468				0.4752	0.4911
LAD Re-levered Beta	**0.8094**				**0.6493**	**0.7327**
S.e	0.0823				0.0592	0.0665
Upper	0.9707				0.7653	0.8631
Lower	0.6481				0.5333	0.6024

Value weighted average

Table 13: Scenario 1 - The longest period of data for the portfolios

	P1	P2	P3	P4	P5	P6
Firm	**APA, ENV**	**AAN, AGL, APA, ENV, GAS**	**APA, DUE, ENV, HDF, AST**	**APA, DUE, ENV, HDF, SKI, AST**	**APA, DUE, ENV, SKI, AST**	**APA, DUE, SKI, AST**
Start	16/06/2000	21/12/2001	16/12/2005	2/03/2007	2/03/2007	2/03/2007
End	28/04/2017	6/10/2006	23/11/2012	23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.5946**	**0.4365**	**0.5213**	**0.5105**	**0.5137**	**0.5068**
S.e	0.0407	0.0668	0.0496	0.0524	0.0394	0.0406
Upper	0.6744	0.5674	0.6185	0.6132	0.5909	0.5864
Lower	0.5148	0.3056	0.4241	0.4078	0.4365	0.4272
LAD Beta	**0.5747**	**0.2897**	**0.4847**	**0.5171**	**0.5585**	**0.5843**
S.e	0.0371	0.0739	0.0348	0.0401	0.0327	0.0339
Upper	0.6474	0.4345	0.5529	0.5957	0.6226	0.6507
Lower	0.5020	0.1449	0.4165	0.4385	0.4944	0.5179
N	880	250	362	299	530	530
R^2	0.1958	0.1469	0.2345	0.242	0.2434	0.2275
Gearing	0.6097	0.5155	0.5943	0.6006	0.6306	0.6143
W	0.9757	1.2111	1.0142	0.9985	0.9235	0.9641
OLS Re-levered Beta	**0.5801**	**0.5287**	**0.5287**	**0.5098**	**0.4744**	**0.4886**
S.e	0.0407	0.0668	0.0496	0.0524	0.0394	0.0406
Upper	0.6599	0.6596	0.6259	0.6125	0.5516	0.5682
Lower	0.5004	0.3977	0.4315	0.4071	0.3972	0.4091
LAD Re-levered Beta	**0.5607**	**0.3509**	**0.4916**	**0.5163**	**0.5158**	**0.5633**
S.e	0.0371	0.0739	0.0348	0.0401	0.0327	0.0339
Upper	0.6334	0.4957	0.5598	0.5949	0.5798	0.6298
Lower	0.4880	0.2060	0.4234	0.4378	0.4517	0.4969

Table 14: Scenario 2 – The longest possible period of data excluding the tech boom and the GFC

	P1	P2	P3	P4	P5	P6
Firm	**APA, ENV**	**AAN, AGL, APA, ENV, GAS**	**APA, DUE, ENV, HDF, AST**	**APA, DUE, ENV, HDF, SKI, AST**	**APA, DUE, ENV, SKI, AST**	**APA, DUE, SKI, AST**
Start	4/01/2002	4/01/2002	16/12/2005	2/03/2007	2/03/2007	2/03/2007
End	28/04/2017	6/10/2006	23/11/2012	23/11/2012	28/04/2017	28/04/2017
OLS Beta	**0.6220**	**0.4347**	**0.5806**	**0.5705**	**0.5791**	**0.5815**
S.e	0.0461	0.0670	0.0516	0.0553	0.0412	0.0426
Upper	0.7124	0.5660	0.6817	0.6789	0.6599	0.6650
Lower	0.5316	0.3034	0.4795	0.4621	0.4983	0.4980
LAD Beta	**0.5566**	**0.2897**	**0.5291**	**0.6003**	**0.6177**	**0.6188**
S.e	0.0454	0.0736	0.0454	0.0487	0.0382	0.0392
Upper	0.6456	0.4340	0.6181	0.6958	0.6926	0.6956
Lower	0.4676	0.1454	0.4401	0.5048	0.5428	0.5420
N	739	249	301	238	469	469
R^2	0.1979	0.1455	0.2978	0.3109	0.2975	0.2855
Gearing	0.6006	0.5119	0.5878	0.5935	0.6215	0.6051
W	0.9984	1.2202	1.0306	1.0162	0.9462	0.9872
OLS Re-levered Beta	**0.6210**	**0.5304**	**0.5984**	**0.5797**	**0.5479**	**0.5740**
S.e	0.0461	0.0670	0.0516	0.0553	0.0412	0.0426
Upper	0.7114	0.6618	0.6995	0.6881	0.6287	0.6575
Lower	0.5307	0.3991	0.4972	0.4713	0.4672	0.4906
LAD Re-levered Beta	**0.5557**	**0.3535**	**0.5453**	**0.6100**	**0.5844**	**0.6109**
S.e	0.0454	0.0736	0.0454	0.0487	0.0382	0.0392
Upper	0.6447	0.4978	0.6343	0.7055	0.6593	0.6877
Lower	0.4667	0.2092	0.4563	0.5146	0.5096	0.5340

Table 15: Scenario 3 – The most recent 5 years

Firm	P1 APA, ENV	P2 AAN, AGL, APA, ENV, GAS	P3 APA, DUE, ENV, HDF, AST	P4 APA, DUE, ENV, HDF, SKI, AST	P5 APA, DUE, ENV, SKI, AST	P6 APA, DUE, SKI, AST
Start	4/05/2012				4/05/2012	4/05/2012
End	28/04/2017				28/04/2017	28/04/2017
OLS Beta	**0.6658**				**0.5707**	**0.5741**
S.e	0.0806				0.0614	0.0623
Upper	0.8238				0.6910	0.6962
Lower	0.5078				0.4504	0.4520
LAD Beta	**0.6525**				**0.6386**	**0.6397**
S.e	0.1004				0.0649	0.0708
Upper	0.8493				0.7658	0.7785
Lower	0.4557				0.5114	0.5009
N	261				261	261
R^2	0.2085				0.2502	0.2471
Gearing	0.5123				0.5554	0.5484
W	1.2193				1.1116	1.1290
OLS Re-levered Beta	**0.8118**				**0.6344**	**0.6482**
S.e	0.0806				0.0614	0.0623
Upper	0.9698				0.7547	0.7703
Lower	0.6538				0.5141	0.5261
LAD Re-levered Beta	**0.7956**				**0.7099**	**0.7222**
S.e	0.1004				0.0649	0.0708
Upper	0.9924				0.8371	0.8610
Lower	0.5988				0.5827	0.5835

The above analyses indicate that, across various scenarios and portfolios, the mean value of the estimated beta for portfolios is approximately 0.57 which varies within the range of 0.35 (LAD estimates on Scenario 1) and 0.81 (OLS estimates on Scenario 3). The median for the estimated betas across various scenarios and portfolios is 0.5741 which is very close with the average value. However, it is noted that most of the estimates are clustered around 0.6. More than two thirds of the estimates (42 out of 60) are below 0.6.

4.2.2. Analysis of thin trading

Findings from the analysis of thin trading using equally weighted and value weighted averages are presented from Table 16 to Table 21 below.

Equally weighted average

Table 16: Scenario 1 - The longest possible period of data for each firm

Portfolio	P1	P2	P3	P4	P5	P6
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
β_{i-1}	0.0362	-0.0644	0.0673	0.0876	0.0757	0.0822
S.E	0.0441	0.0617	0.0577	0.0599	0.0407	0.0416
β_i	0.5792	0.4418	0.5979	0.5771	0.5077	0.4875
S.E	0.0441	0.0615	0.0577	0.0601	0.0408	0.0417
β_{i+1}	-0.0912	-0.0675	-0.0395	-0.0299	-0.054	-0.0587
S.E	0.0442	0.0614	0.0577	0.06	0.0408	0.0417
β^D_i	0.5242	0.3099	0.6257	0.6348	0.5294	0.5110
S.E						
β^{OLS}_i	0.5810	0.4284	0.5974	0.5750	0.5068	0.4865
S.E	0.0441	0.0614	0.0575	0.0598	0.0408	0.0417
$\beta^{OLS}_i = \beta^D_i$	1.2880	1.9300	-0.4922	-1.0000	-0.5539	-0.5875
N	878	249	361	298	529	529

Table 17: Scenario 2 - The longest possible period of data excluding the tech boom and the GFC

Portfolio	P1	P2	P3	P4	P5	P6
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
β_{i-1}	0.0034	-0.0646	-0.0448	-0.0358	0.0064	-0.0032
S.E	0.0429	0.0624	0.0502	0.0556	0.041	0.0436
β_i	0.5912	0.4414	0.5839	0.5764	0.5538	0.554
S.E	0.0429	0.0618	0.0501	0.0557	0.0412	0.0438
β_{i+1}	-0.0617	-0.0678	-0.0115	-0.0008	-0.0251	-0.0216
S.E	0.0428	0.0617	0.0499	0.0554	0.0411	0.0436
β^D_i	0.5329	0.3090	0.5276	0.5398	0.5351	0.5292
S.E						
β^{OLS}_i	0.5944	0.4283	0.5870	0.5748	0.5514	0.5543
S.E	0.0426	0.0616	0.0493	0.0546	0.0407	0.0433
$\beta^{OLS}_i = \beta^D_i$	1.4437	1.9367	1.2049	0.6410	0.4005	0.5797
N	735	247	298	235	466	466

Table 18: Scenario 3 – The most recent 5 years of data ending on 30 April 2017

Portfolio	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
b_{i-1}	0.0937				0.0647	0.0642
s.e	0.0827				0.0616	0.0624
b_i	0.662				0.5331	0.5392
s.e	0.0826				0.0615	0.0623
b_{i+1}	-0.103				-0.1021	-0.1412
s.e	0.0831				0.0619	0.0626
b^D_i	0.6527				0.4957	0.4622
s.e						
b^{OLS}_i	0.6623				0.5356	0.5435
s.e	0.0820				0.0613	0.0625
$b^{OLS}_i = b^D_i$	0.1171				0.6509	1.3008
N	259				259	259

Value weighted average

Table 19: Scenario 1 - The longest possible period of data for each firm

Portfolio	P1	P2	P3	P4	P5	P6
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
β_{i-1}	0.0285	-0.0508	0.0528	0.0729	0.0713	0.073
S.E	0.0406	0.0673	0.0498	0.0524	0.0393	0.0405
β_i	0.5917	0.4489	0.5198	0.5105	0.5137	0.5067
S.E	0.0407	0.067	0.0497	0.0525	0.0394	0.0406
β_{i+1}	-0.1028	-0.0504	-0.0665	-0.0563	-0.0691	-0.0719
S.E	0.0407	0.0669	0.0497	0.0525	0.0394	0.0406
β^D_i	0.5174	0.3477	0.5061	0.5271	0.5159	0.5078
S.E						
β^{OLS}_i	0.5946	0.4365	0.5213	0.5105	0.5137	0.5068
S.E	0.0407	0.0668	0.0496	0.0524	0.0394	0.0406
$\beta^{OLS}_i = \beta^D_i$	1.8968	1.3293	0.3065	-0.3168	-0.0558	-0.0246
N	878	249	361	298	529	529

Table 20: Scenario 2 - The longest possible period of data excluding the tech boom and the GFC

Portfolio	P1	P2	P3	P4	P5	P6
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
β_{i-1}	-0.0091	-0.0541	-0.047	-0.0373	0.0045	0.0008
S.E	0.0464	0.068	0.0524	0.0562	0.0415	0.0429
β_i	0.6123	0.447	0.573	0.567	0.5771	0.5782
S.E	0.0464	0.0673	0.0523	0.0564	0.0416	0.043
β_{i+1}	-0.0561	-0.0505	-0.0156	-0.0048	-0.0347	-0.0341
S.E	0.0463	0.0672	0.0521	0.056	0.0415	0.0429
β^D_i	0.5471	0.3424	0.5104	0.5249	0.5469	0.5449
S.E						
β^{OLS}_i	0.6220	0.4347	0.5806	0.5705	0.5791	0.5815
S.E	0.0461	0.0670	0.0516	0.0553	0.0412	0.0426
$\beta^{OLS}_i = \beta^D_i$	1.6247	1.3776	1.3605	0.8246	0.7816	0.8592
N	735	247	298	235	466	466

Table 21: Scenario 3 – The most recent 5 years of data ending on 30 April 2017

Portfolio	P1	P2	P3	P4	P5	P6
Firms	APA, ENV	AAN, AGL, APA, ENV, GAS	APA, DUE, ENV, HDF, AST	APA, DUE, ENV, HDF, SKI, AST	APA, DUE, ENV, SKI, AST	APA, DUE, SKI, AST
b_{i-1}	0.0823				0.0719	0.0717
s.e	0.0808				0.0614	0.062
b_i	0.6626				0.5675	0.5702
s.e	0.0806				0.0613	0.062
b_{i+1}	-0.1582				-0.1326	-0.1481
s.e	0.0811				0.0616	0.0623
b^D_i	0.5867				0.5068	0.4938
s.e						
b^{OLS}_i	0.6658				0.5707	0.5741
s.e	0.0806				0.0614	0.0623
$b^{OLS}_i = b^D_i$	0.9814				1.0407	1.2889
N	259				259	259

4.2.3. Analysis of Stability and Sensitivity

Appendix 2 presents the results from this study. Empirical evidence from this study indicate that there is no evidence to support the view that the recursive estimation conducted in this study provides any systematic or strong evidence of parameter instability in both OLS and LAD estimates of beta for fixed weight portfolios.

5. An analysis of a structural break in the estimates of equity beta

The analysis of structural break is conducted at both levels including the individual firm level and the portfolio level. Findings from the test can be summarised from Table 22 and Table 23 when equity beta is used; and from Table 24 and Table 25 when asset beta is used. It is noted that the dates on which the structural breaks may occur on the empirical ground, and the associate tests outcomes, are the same regardless of asset beta or equity beta is used in the test. This may be due to the assumption in relation to the transformation from equity beta into asset beta using a constant gearing.

This study identifies some possible breaks on the empirical ground. We note that the possible breaks found in this study on the empirical ground are not the same with those from CEG’s 2016 study. As discussed below, we consider that to the extent any structural breaks should be analysed using a two-step approach and not just empirical analysis. In any case, the findings from the estimates of beta for both prior to and post possible break points, which should not be call “structural breaks”, do provide convincing evidence to support the view that beta falls within the range of 0.4 and 0.7.

Table 22: Structural break test for individual firms using equity beta

Firm	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
AAN	20/10/2000	17/08/2007	21/02/2003	9.1392	**0.0392**	0.5426	0.1733	0.8483
AGL	29/05/1992	6/10/2006	31/12/1999	11.6530	**0.0122**	0.4076	0.5954	0.1515
APA	16/06/2000	28/04/2017	16/12/2005	6.0243	0.1591			
DUE	13/08/2004	28/04/2017	28/12/2007	5.8285	0.1733			
ENV	29/08/1997	12/09/2014	2/01/2009	6.9044	0.1079			
GAS	21/12/2001	10/11/2006	1/04/2005	3.6617	0.4290			
HDF	17/12/2004	23/11/2012	20/02/2009	11.3470	**0.0141**	0.9478	0.5706	1.4591
SKI	2/03/2007	28/04/2017	21/11/2008	7.1317	**0.0975**	0.4252	0.2196	0.5342
AST	16/12/2005	28/04/2017	29/05/2009	26.4041	**0.0000**	0.3942	0.1250	0.6530
Firm	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
AAN	21/02/2003	17/08/2007	30/06/2006	2.6973	0.6193			
AGL	31/12/1999	6/10/2006	28/03/2003	20.9859	**0.0001**	0.1515	-0.1439	0.7007
HDF	20/02/2009	12/09/2014	25/09/2009	27.5133	**0.0000**	1.4591	3.8141	0.5728
SKI	21/11/2008	28/04/2017	30/07/2010	4.4601	0.3102			
AST	29/05/2009	28/04/2017	28/10/2011	4.6374	0.2881			
Firm	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
AGL	28/03/2003	6/10/2006	4/02/2005	2.6373	0.6329			
HDF	25/09/2009	12/09/2014	16/12/2011	18.6344	**0.0004**	0.5728	0.7456	-0.5176
Firm	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
HDF	16/12/2011	12/09/2014	13/07/2012	17.1168	0.0009	-0.5176	-1.1001	0.7470

Table 23: Structural break test for the portfolios using equity beta

Portfolio	Average	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
P1	Equal Weight	16/06/2000	28/04/2017	25/05/2007	8.2137	**0.0599**	0.5810	0.3346	0.6436
	Value Weight			20/01/2006	8.2726	**0.0583**	0.5946	0.3291	0.6461
P2	Equal Weight	21/12/2001	6/10/2006	28/03/2003	13.2672	**0.0057**	0.4284	0.1507	0.5955
	Value Weight			28/03/2003	16.4993	**0.0012**	0.4365	0.0929	0.6376
P3	Equal Weight	16/12/2005	23/11/2012	**6/02/2009**	7.5477	**0.0809**	0.5974	0.4490	0.7578
	Value Weight			6/02/2009	2.8270	0.5907			
P4	Equal Weight	2/03/2007	23/11/2012	5/12/2008	5.5077	0.1991			
	Value Weight			9/05/2008	4.0236	0.3710			
P5	Equal Weight	2/03/2007	28/04/2017	5/12/2008	5.8010	0.1754			
	Value Weight			5/12/2008	4.6900	0.2818			
P6	Equal Weight	2/03/2007	28/04/2017	5/12/2008	5.2967	0.2180			
	Value Weight			5/12/2008	4.1794	0.3482			
P6	Equal Weight	2/03/2007	28/04/2017	**7/08/2009**	2.3344	0.1265	0.4865	0.4135	0.5447
	Value Weight			**7/08/2009**	2.9024	**0.0884**	0.5068	0.4281	0.5706

Portfolio	Average	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
P1	Equal Weight	25/05/2007	28/04/2017	12/09/2014	2.2458	0.7252			
	Value Weight	20/01/2006	28/04/2017	9/05/2008	3.1436	0.5247			
P2	Equal Weight	28/03/2003	6/10/2006	24/12/2004	1.6597	0.8699			
	Value Weight	28/03/2003	6/10/2006	24/12/2004	2.0968	0.7617			
P3	Equal Weight	6/02/2009	23/11/2012	**25/09/2009**	12.7389	**0.0073**	0.7578	1.2871	0.5438
P6	Value Weight	**7/08/2009**	28/04/2017	4/03/2016	2.5084	0.6625			

Portfolio	Average	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
P3	Equal Weight	25/09/2009	23/11/2012	**16/12/2011**	13.8275	**0.0044**	0.5438	0.6272	0.0258

Portfolio	Average	Start	End	Possible Break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to Breakpoint	Beta after Breakpoint
P3	Equal Weight	16/12/2011	23/11/2012	21/09/2012	1.6338	0.8762			

Table 24: Structural break test for individual firms using asset beta

Firm	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
AAN	20/10/2000	17/08/2007	21/02/2003	9.1392	**0.0392**	0.3321	0.1061	0.5191
AGL	29/05/1992	6/10/2006	31/12/1999	11.6530	**0.0122**	0.2743	0.4008	0.1020
APA	16/06/2000	28/04/2017	16/12/2005	6.0243	0.1591			
DUE	13/08/2004	28/04/2017	28/12/2007	5.8285	0.1733			
ENV	29/08/1997	12/09/2014	2/01/2009	6.9044	0.1079			
GAS	21/12/2001	10/11/2006	1/04/2005	3.6617	0.4290			
HDF	17/12/2004	23/11/2012	20/02/2009	11.3470	**0.0141**	0.5209	0.3136	0.8019
SKI	2/03/2007	28/04/2017	21/11/2008	7.1317	**0.0975**	0.1565	0.0808	0.1966
AST	16/12/2005	28/04/2017	29/05/2009	26.4041	**0.0000**	0.1596	0.0506	0.2463

Firm	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
AAN	21/02/2003	17/08/2007	30/06/2006	2.6973	0.6193			
AGL	31/12/1999	6/10/2006	28/03/2003	20.9859	**0.0001**	0.1020	-0.0969	0.4717
HDF	20/02/2009	12/09/2014	25/09/2009	27.5133	**0.0000**	0.8019	2.0962	0.3148
SKI	21/11/2008	28/04/2017	30/07/2010	4.4601	0.3102			
AST	29/05/2009	28/04/2017	28/10/2011	4.6374	0.2881			

Firm	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
AGL	28/03/2003	6/10/2006	4/02/2005	2.6373	0.6329			
HDF	25/09/2009	12/09/2014	16/12/2011	18.6344	**0.0004**	0.3148	0.4098	-0.2845

Firm	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
HDF	16/12/2011	12/09/2014	13/07/2012	17.1168	**0.0009**	-0.2845	-0.6046	0.4106

Table 25: Structural break test for the portfolios using asset beta

Portfolio	Average	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
P1	Equal Weight	16/06/2000	28/04/2017	25/05/2007	8.2137	**0.0599**	0.2267	0.1306	0.2512
	Value Weight			20/01/2006	8.2726	**0.0583**	0.2321	0.1284	0.2522
P2	Equal Weight	21/12/2001	6/10/2006	28/03/2003	13.2672	**0.0057**	0.2075	0.0730	0.2885
	Value Weight			28/03/2003	16.4993	**0.0012**	0.2115	0.0450	0.3089
P3	Equal Weight	16/12/2005	23/11/2012	6/02/2009	7.5477	**0.0809**	0.2424	0.1822	0.3074
	Value Weight			6/02/2009	2.8270	0.5907			
P4	Equal Weight	2/03/2007	23/11/2012	5/12/2008	5.5077	0.1991			
	Value Weight			9/05/2008	4.0236	0.3710			
P5	Equal Weight	2/03/2007	28/04/2017	5/12/2008	5.8010	0.1754			
	Value Weight			5/12/2008	4.6900	0.2818			
P6	Equal Weight	2/03/2007	28/04/2017	5/12/2008	5.2967	0.2180			
	Value Weight			5/12/2008	4.1794	0.3482			
P6	Equal Weight	2/03/2007	28/04/2017	**7/08/2009**	2.3344	0.1265	0.1876	0.1595	0.2101
	Value Weight			**7/08/2009**	2.9024	**0.0884**	0.1955	0.1651	0.2200

Portfolio	Average	Start	End	Possible break date	Supremum Wald test	P-value	Beta for whole sample	Beta prior to breakpoint	Beta after breakpoint
P1	Equal Weight	25/05/2007	28/04/2017	12/09/2014	2.2458	0.7252			
	Value Weight	20/01/2006	28/04/2017	9/05/2008	3.1436	0.5247			
P2	Equal Weight	28/03/2003	6/10/2006	24/12/2004	1.6597	0.8699			
	Value Weight	28/03/2003	6/10/2006	24/12/2004	2.0968	0.7617			
P3	Equal Weight	6/02/2009	23/11/2012	25/09/2009	12.7389	**0.0073**	0.3074	0.5222	0.2206
P6	Value Weight	**7/08/2009**	28/04/2017	4/03/2016	2.5084	0.6625			
P3	Equal Weight	25/09/2009	23/11/2012	16/12/2011	13.8275	**0.0044**	0.2206	0.2545	0.0105
P3	Equal Weight	16/12/2011	23/11/2012	21/09/2012	1.6338	0.8762			

We are of the view that it is appropriate to follow a two-step approach to identify any structural break in the data.

1. First, a major event during a period is examined to consider a possible structural break in the data, to be named “the necessary condition”; and
2. Second, structural break tests such as a very popular Chow’s test and the others are conducted to examine realised data to confirm if the structural break did occur during the period as anticipated, to be named “the sufficient condition”.

Each of these two steps is discussed in turn below.

Step 1: An establishment of a major event

As the first step, it is necessary to identify any possible structural break recognizing a major event during the period under examination. For example, the Persian Gulf crisis of 1991 was examined to consider the international response of the equity prices (Malliaris and Urrutia, 1995).[36] Nikkenin et al (2008)[37] used the September 11 attack in the US to examine the impact of this event on the volatility stock markets in six different regions. The 1997 Asian financial crisis; the collapse of oil prices in 1998; and the adoption of the price band mechanism by OPEC in 2000 were examined to consider sudden changes in volatility for five Gulf stock markets (Hammoudeh and Li, 2008).[38]

As an illustration, CEG for the businesses found a break in 2009 and 2014. We found a break in 2009 during the Global Financial Crisis. This structural break could be explained by the effects of the GFC. We have conducted a comprehensive search to identify any major event which could be used to explain a structural break in beta in Australia in 2014.[39] Significant events happening in 2014 include the Ukrainian Revolution (February 18);[40] Malaysia Airlines Flight 370 (March 8); Russia formally annexes Crimea (March 21); Islamic State of Iraq forces seize control of government offices and other important buildings in the northern city of Mosul (June 11) and others. We are not convinced that one of these significant events in 2014 can be used to explain a structural break in Australian betas. As a consequence, the proposed structural break of August 2014 found by CEG, which is not found in our 2017 update, is viewed as a random or spurious finding. In addition, we note

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36 Malliaris & Urrutia (1995), The Impact of the Persian Gulf Crisis on National Equity Markets, *Advances in International Banking and Finance*, 1, 43-65.

37 Nikkinen, J., Omran, M., P., Sahlstrom, P. & Aijo, J. (2008) Stock Returns and Volatility Following the September 11 Attacks: Evidence from 53 Equity Markets, *International Review of Financial Analysis*, 17, 27-46.

38 Hammoudeh, S. and Li, H. (2008), Sudden Changes in Volatility in Emerging Markets: The Case of Gulf Arab Stock Markets, *International Review of Financial Analysis*, 17, 47-63.

39 For details, please visit http://www.onthisday.com/date/2014, accessed on 25 May 2017.

40 Ukrainian Revolution of 2014 begins as protesters, riot police and unknown shooters take part in violent events in the capital, Kiev, culminating after five days in the ouster of President Viktor Yanukovych.

Partington and Satchell's view that the breakpoint test would be more reliable if the breakpoint detected was closer to the centre of the test sample. The fact that the break is near the end of the sample deems it to be less reliable. Importantly, we need to consider the size of the sample in assessing structural breaks. For example, CEG's proposed August 2014 structural break is identified from Portfolio 6 which includes only 4 firms in the data period from June 2000 (for the APA Group) to October 2016. As such, we are of the view that this structural break is less reliable.[41]

Step 2: An empirical examination of a structural break around a major event using various tests

In their advice, Partington and Satchell considered that the Chow test is an appropriate test for a structural break. Partington and Satchell also considered that the Quandt Andrews test is also a suitable test for a structural break, although this test is less restrictive. We note that the Chow test is used to test for break points or structural changes in a model by partitioning the data into two separate parts. As such, the Chow test is a very restrictive test in that the point of the structural break should be pre-determined in advance of the test. Other tests including the Quandt Andrews test allow the point of the structural break to be determined from the data. We are open to the use of various tests for structural breaks because an exact break date may not be exactly pre-determined. From our perspective the structural break under investigation may be pre-determined or not, as long as the above two-step approach is considered. As such, we are of the view that a higher hurdle is required when identifying a structural break.

In conclusion, we consider that it is appropriate to adopt a two-step approach when testing for structural breaks in data. The first step will enable identification of major event(s) which may cause a discontinuity in the data used for estimating parameters of interest. Then in the second step various tests for structural breaks can be employed to confirm the presence of one or more breaks as anticipated in the first step. If one or more breaks do occur during the period under investigation then this evidence will inform estimation of the parameters.

41 Partington, G. and Satchell, S. (2017), Report to the AER: Discussion of Submissions on the Cost of Equity, May 2017, page 15.

6. Conclusions

This study is conducted to provide an estimate of equity beta for regulated utilities companies in Australia. The study is extended to include data until 30 April 2017.

Equity betas are estimated for the following three different scenarios: (i) the longest possible period of data for each firm in the benchmark sample including nine Australian energy businesses (Scenario 1); (ii) the longest possible period of data for each firm in the sample after the tech boom (from 3 July 1998 to 28 December 2001) and the GFC (from 5 September 2008 to 30 October 2009) (Scenario 2); and (iii) the most recent 5 years of data ending on 30 April 2017 (Scenario 3). Analyses in this study are conducted at individual firm and portfolio levels. At the portfolio level, both equally weighted average and value weighted average are used. The approach including data sources, econometric techniques (including both OLS and LAD), and other tests (structural break, thin trading, stability of estimated parameter) is conducted in consistence with that utilised by Henry.

Across all scenarios, methods, and portfolios, key findings from this study can be summarised as below.

- *First*, at the individual firm level, the highest estimate of 1.3022 is for HDF and the lowest estimate of 0.2705 is for DUET. The mean value of estimated beta is 0.5754 whereas the median is 0.5424. It is noted that more than 50 per cent of the estimates are lower than the mean estimated value when all estimates from various scenarios are considered.
- *Second*, at the portfolio level, across various scenarios and portfolios, the mean value of the estimated beta for portfolios is approximately 0.5744 which varies within the range of 0.3509 (LAD estimates on Scenario 1) and 0.8118 (OLS estimates on Scenario 3). The median for the estimated betas across various scenarios and portfolios is 0.5741 which is very close with the average value of 0.5744. However, it is noted that most of the estimates are clustered around 0.6. More than two thirds of the estimates (42 out of 60) are below 0.6.
- *Third*, there is no strong evidence of thin trading in this analysis at both individual firms and portfolio levels. As such, the estimated betas from this study are robust and can be used for the regulatory purpose.
- *Fourth*, no sensible evidence of a structural break in the estimates of beta is found at both individual firm and portfolio levels. There is no theoretical justification for any “break” found on the empirical ground. As a result, the two-step approach should be considered for any possible break of the estimates of equity beta.

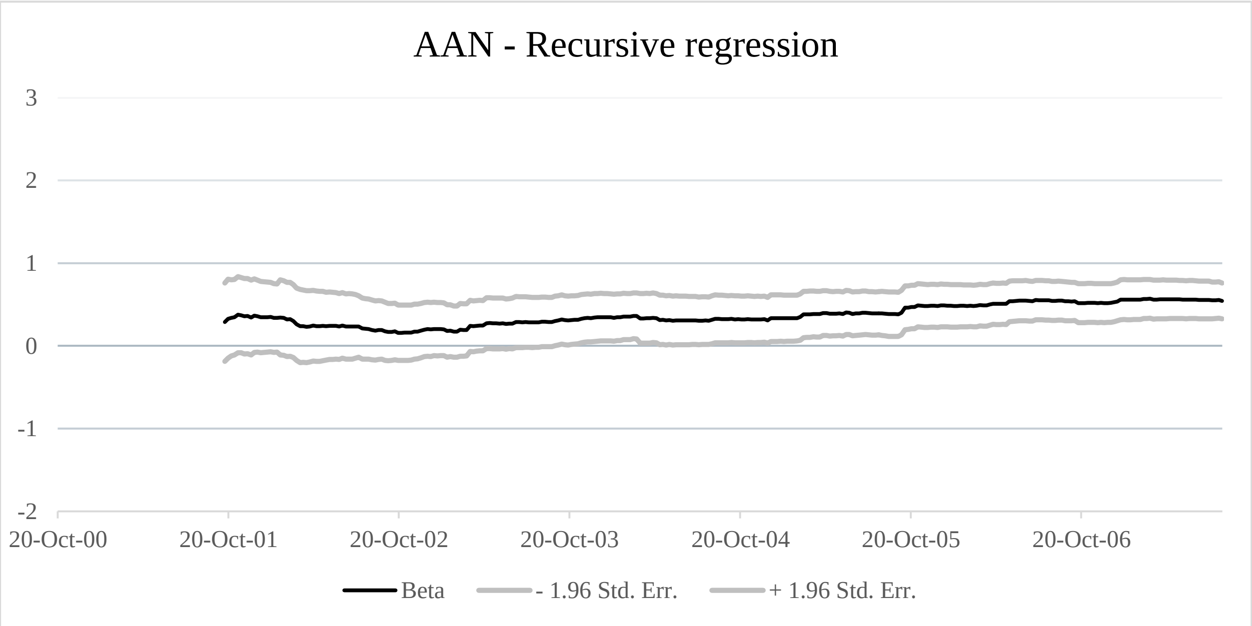
- *Fifth*, a stability of estimated parameter is conducted in this study. It is concluded that there is no strong evidence to support instability of the estimated parameter and that the range of 0.4 to 0.7 is supported from this analysis.

On balance, when each of the beta estimates across scenarios, methods, and portfolios is considered independently, two thirds of the above estimates are less than 0.6. In addition, the mean and median values are also less than 0.6. Findings from this study support the range of 0.4 – 0.7 and that there is no evidence to adopt a higher estimated beta.

Appendix 1:

Recursive and Rolling Regressions, Individual Firms

Figure 3: AAN 20 Oct 2000 – 17 Aug 2007



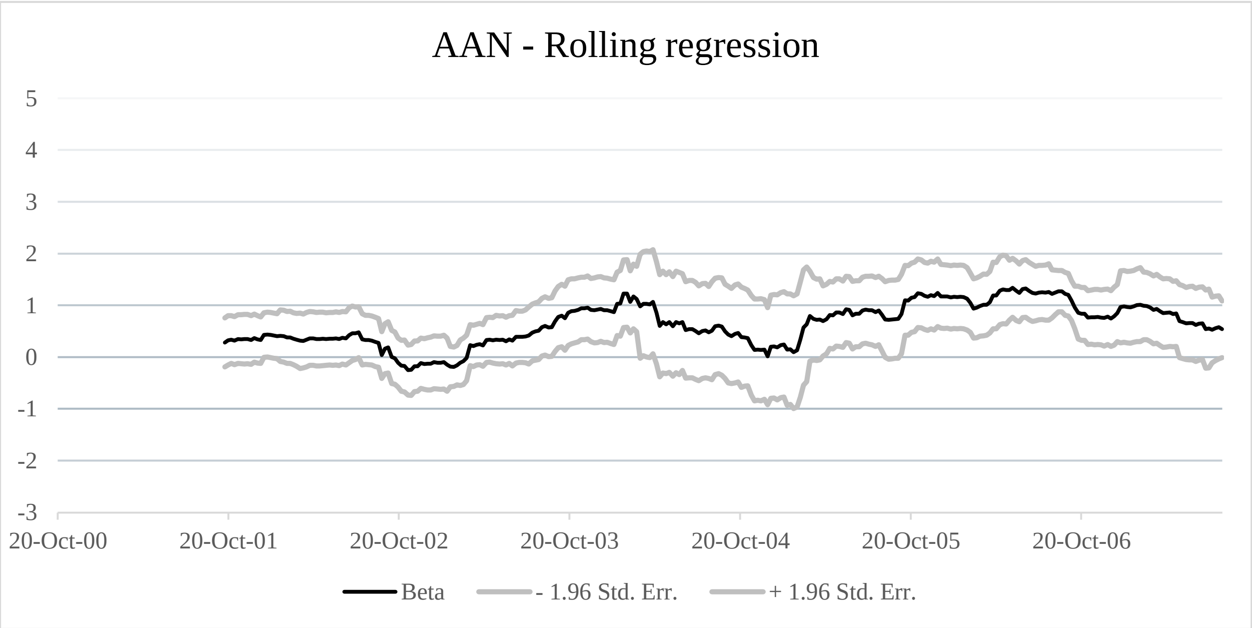
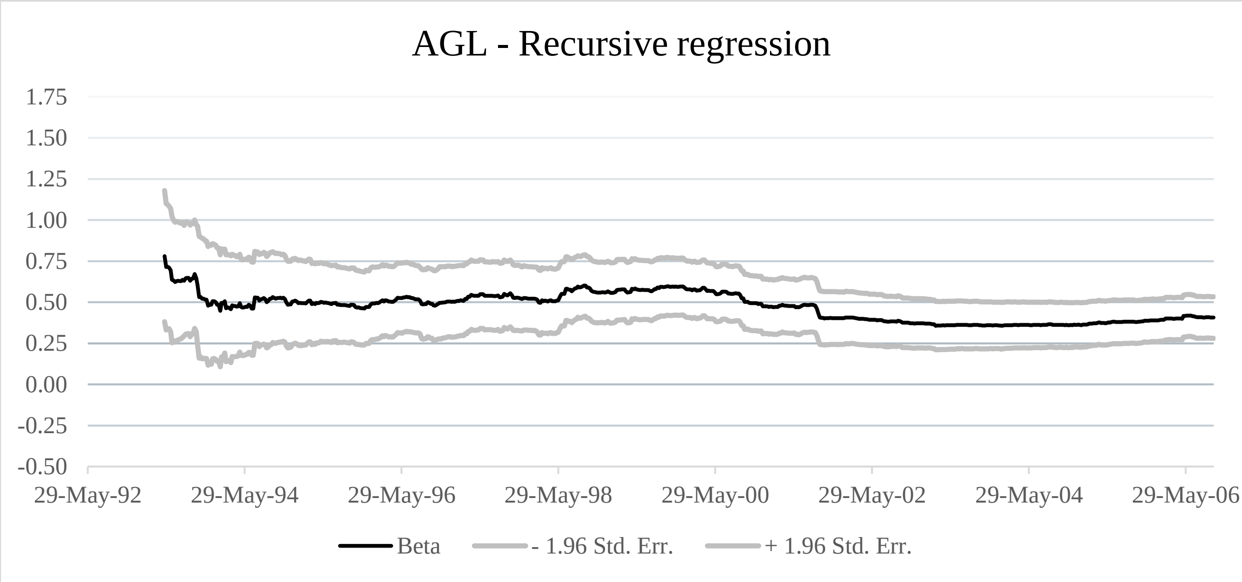


Figure 4: AGL 29 May 1992 – 06 Oct 2006



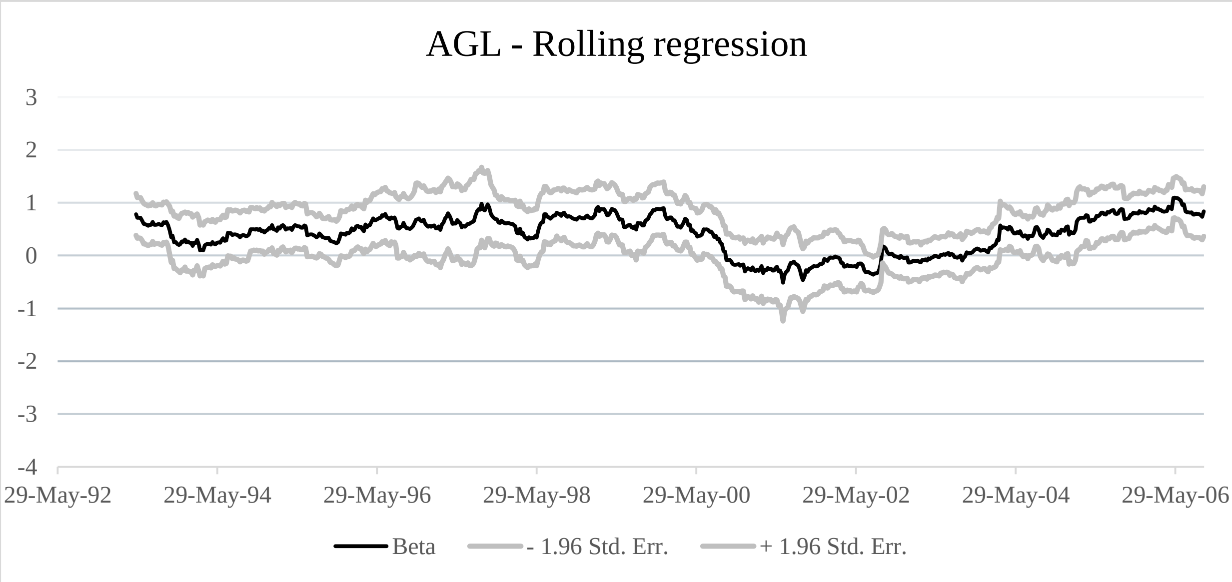
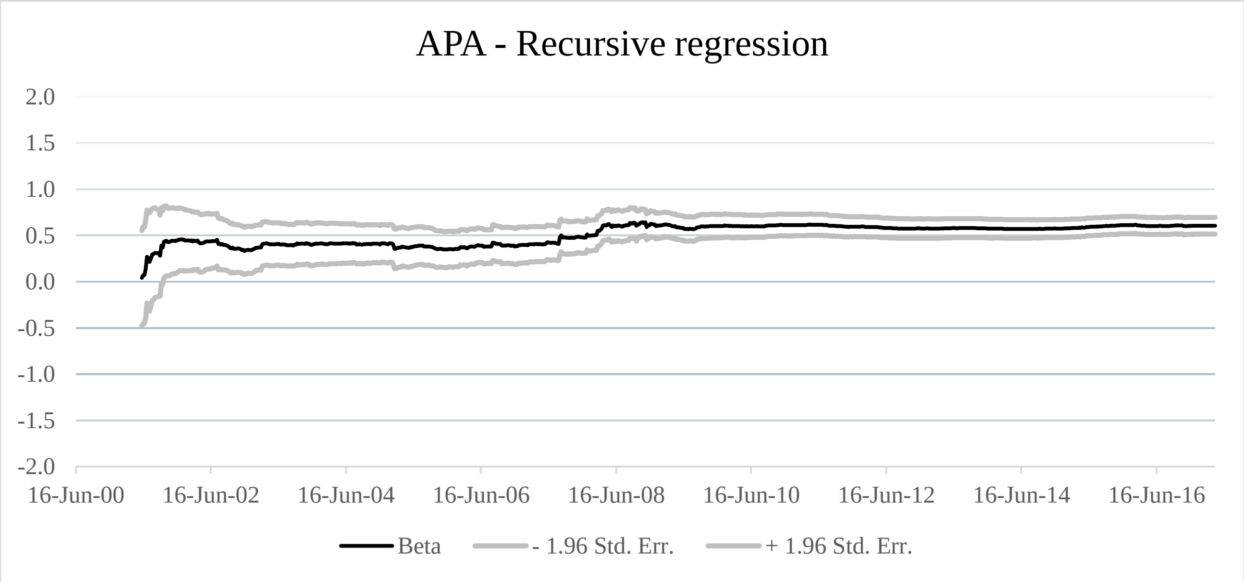


Figure 5: APA 16 Jun 2000 – 28 Apr 2017



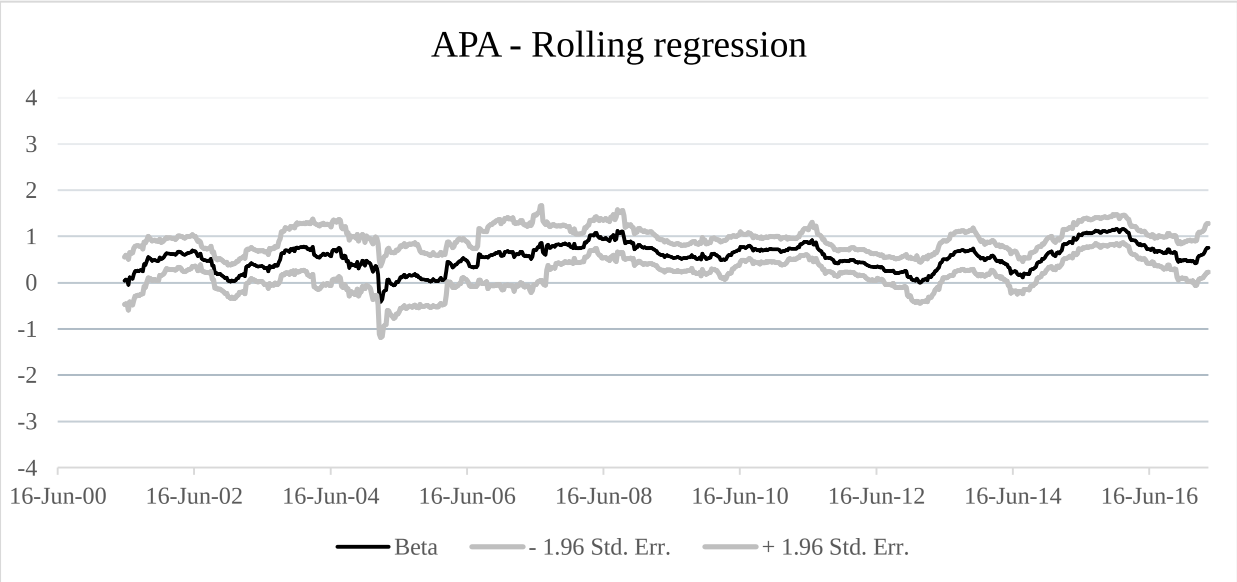
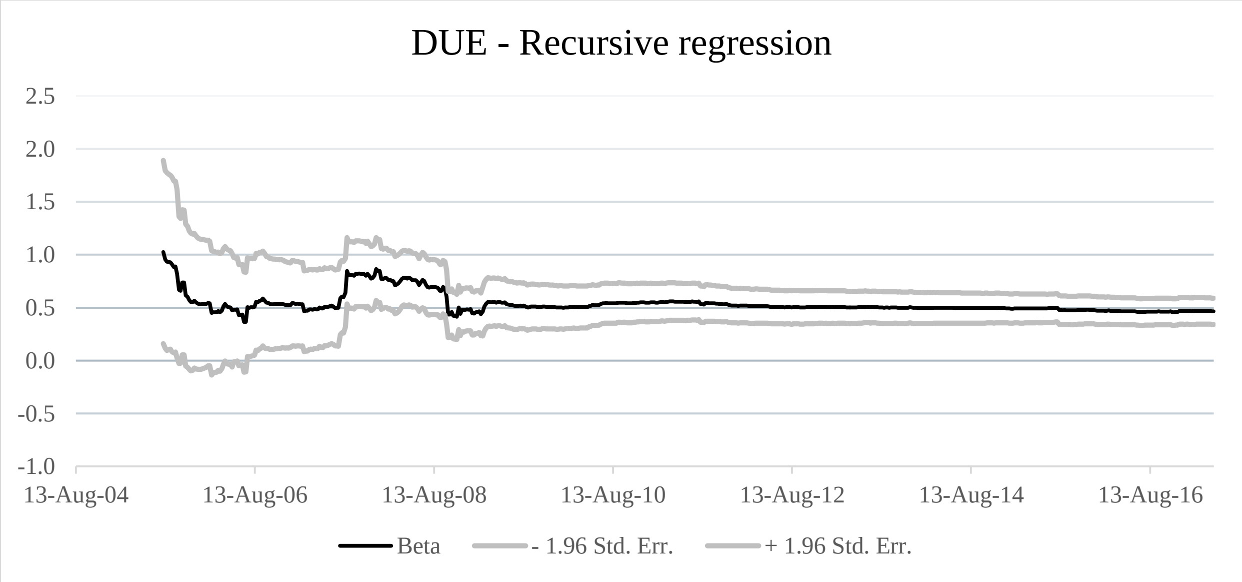


Figure 6: DUE 13 Aug 2004 - 28 Apr 2017



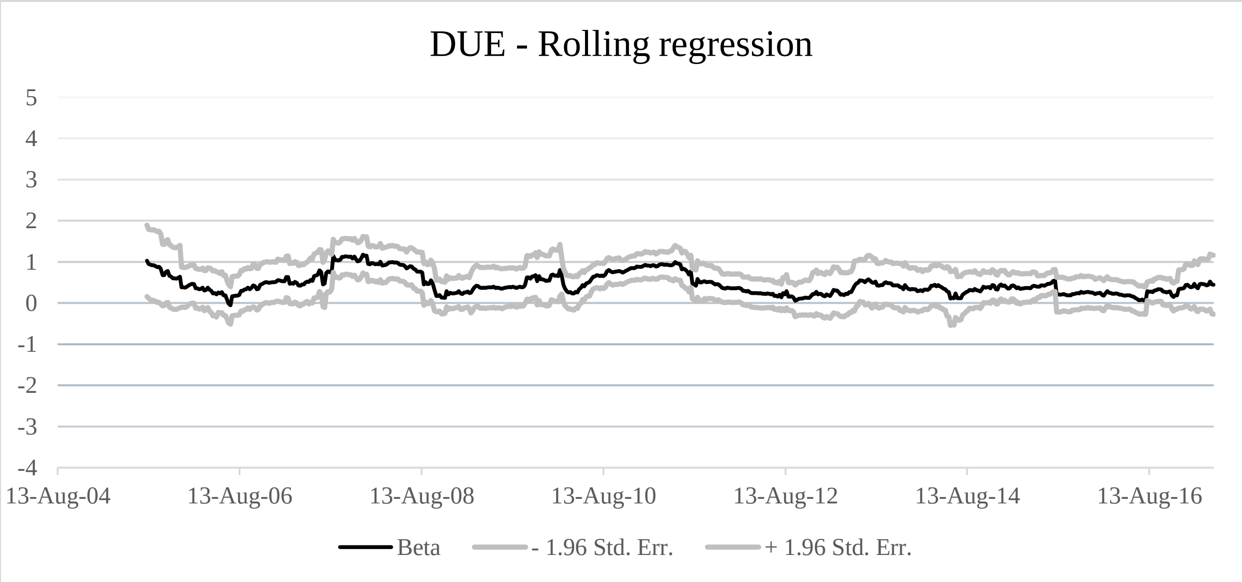
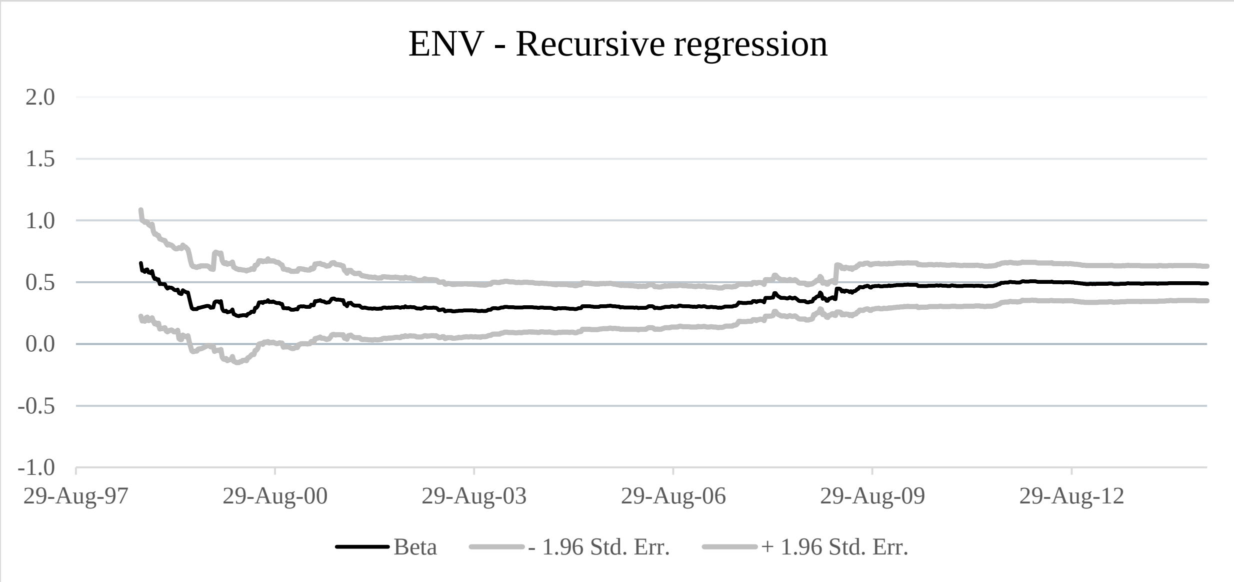


Figure 7: ENV 29 Aug 1997 – 12 Sep 2014



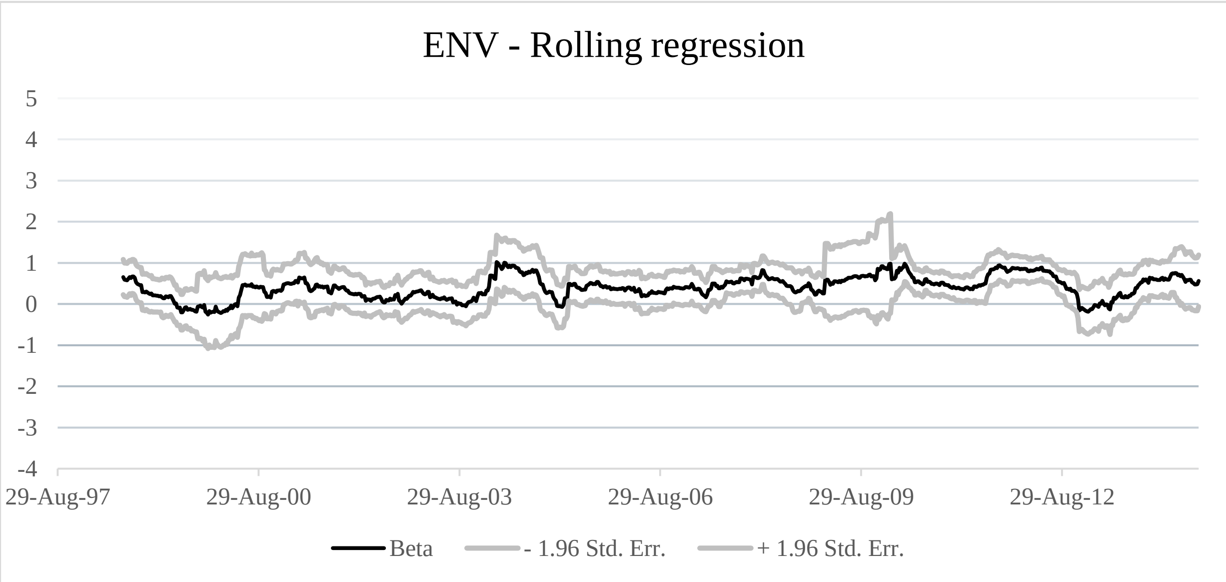
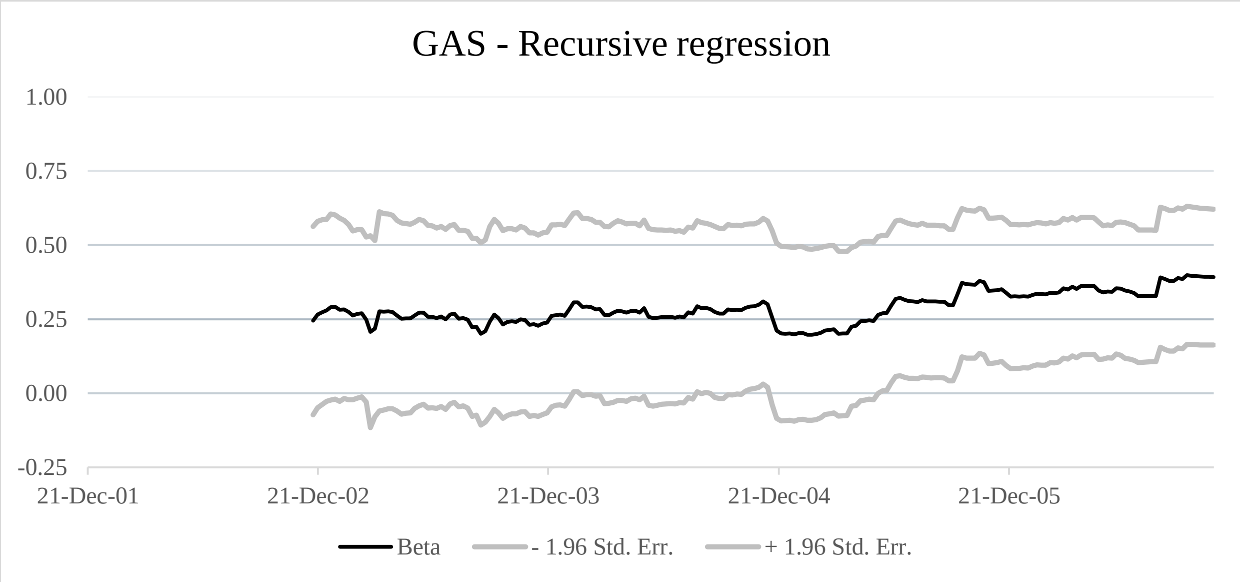


Figure 8: GAS 21 Dec 2001 – 10 Nov 2006



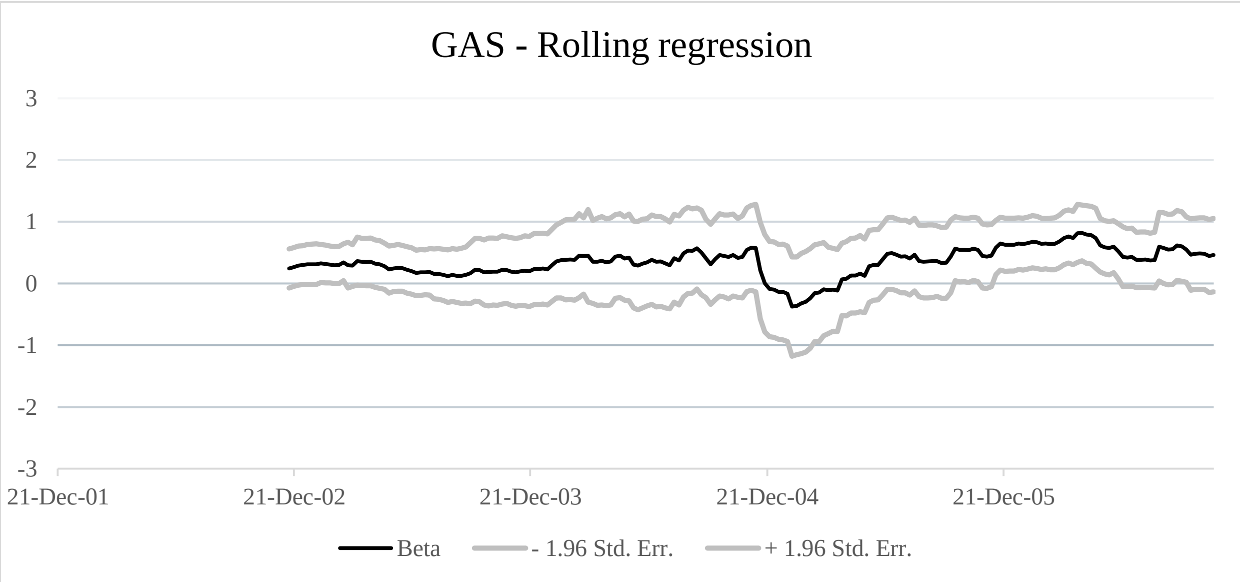
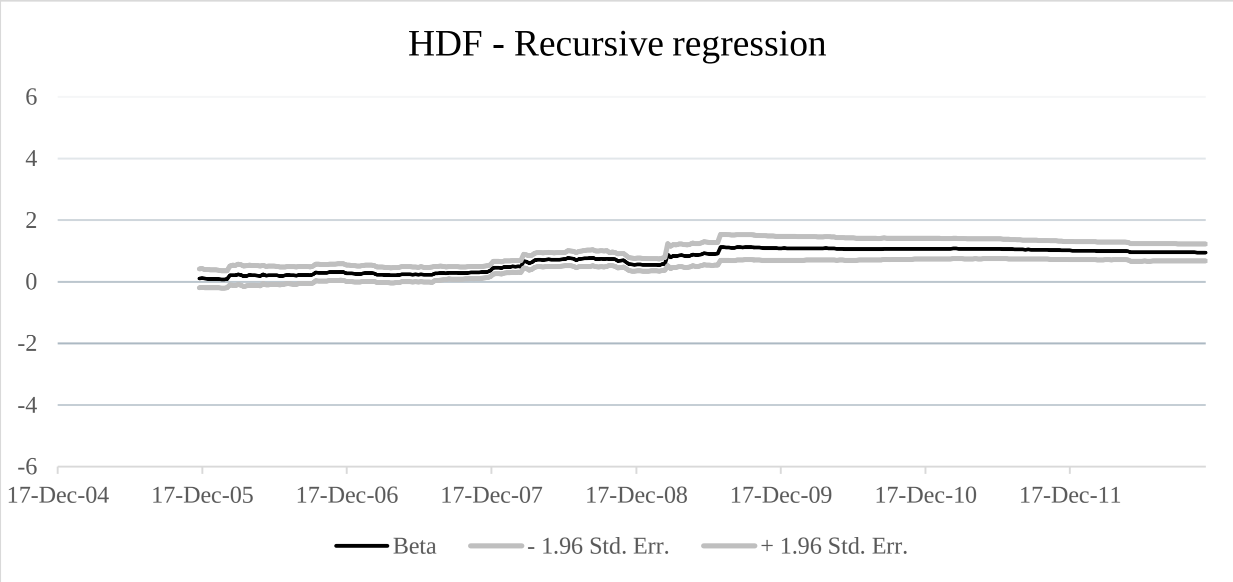


Figure 9: HDF 17 Dec 2004 – 23 Nov 2012



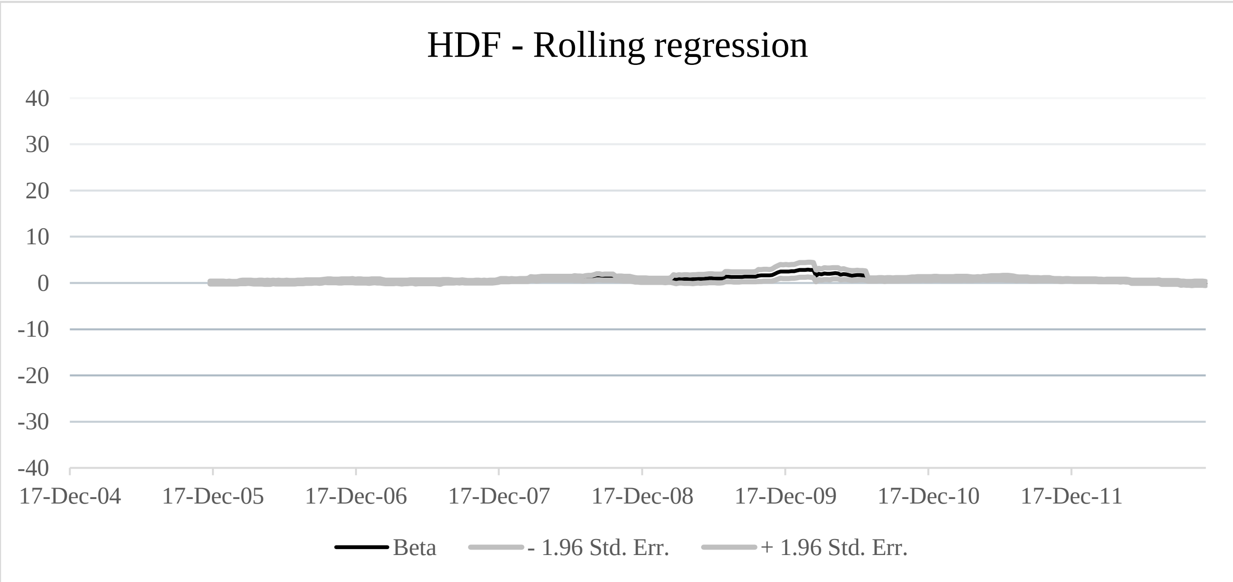
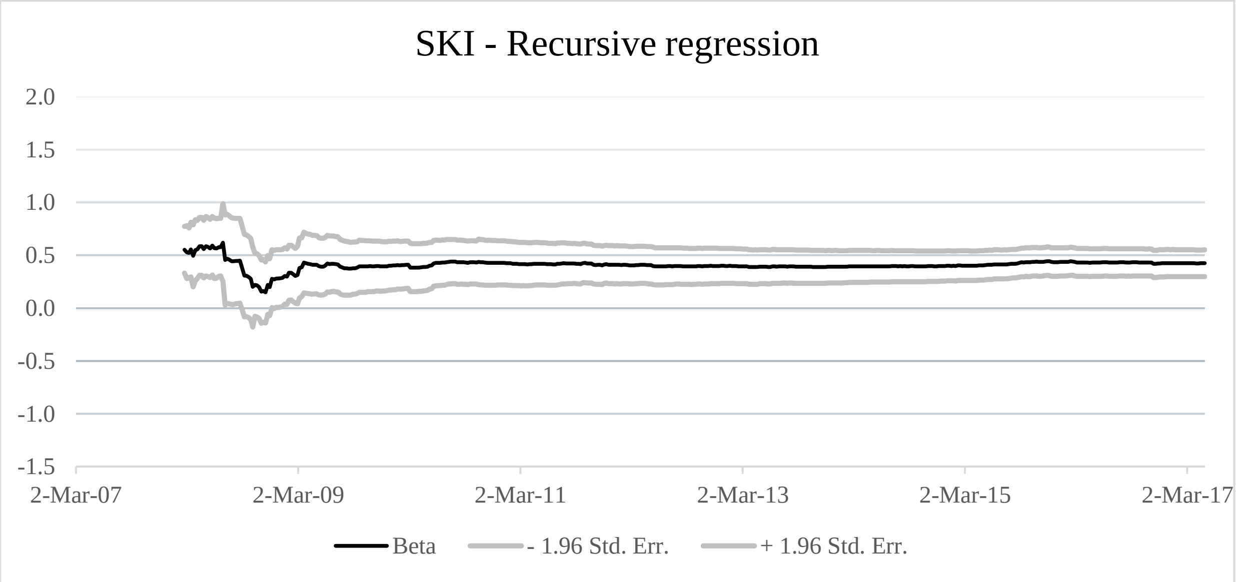


Figure 10: SKI 02 Mar 2007 - 28 Apr 2017



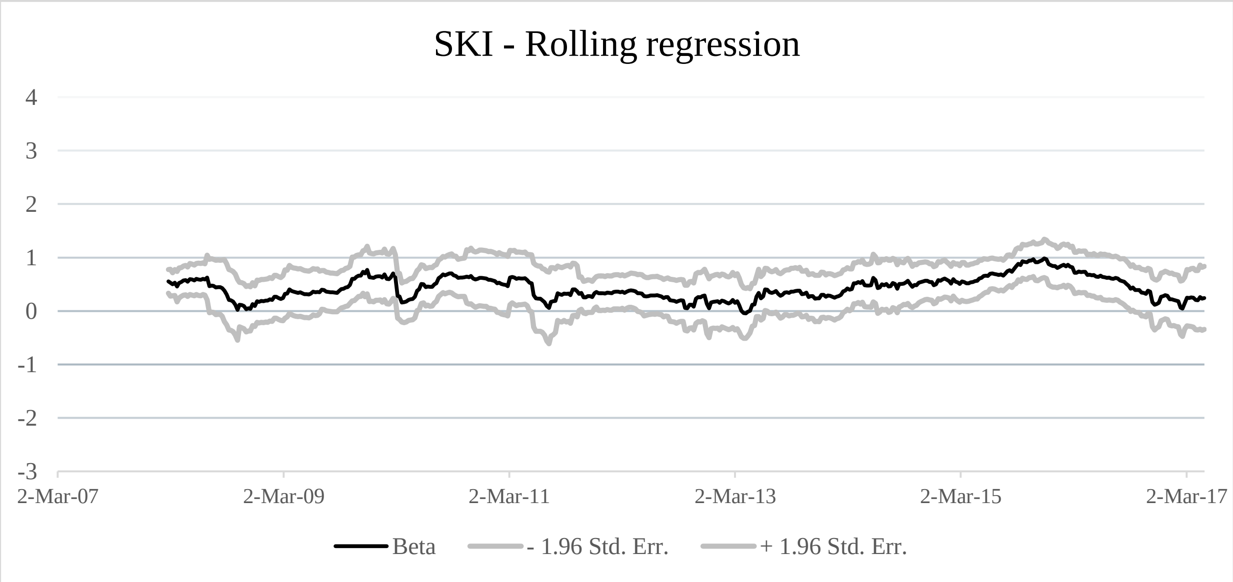
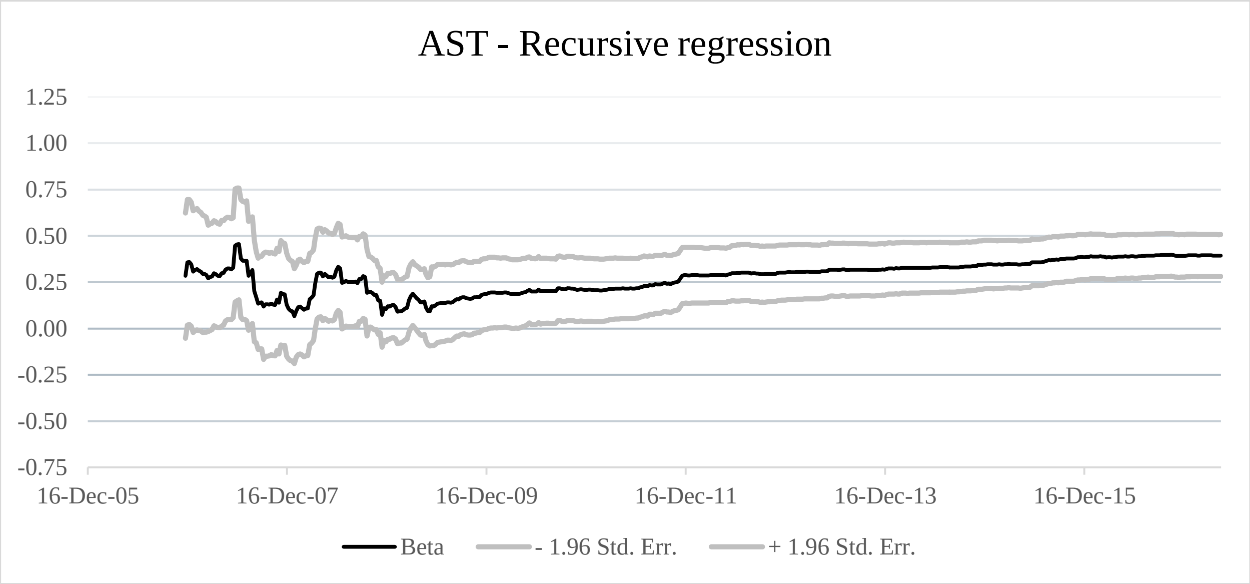
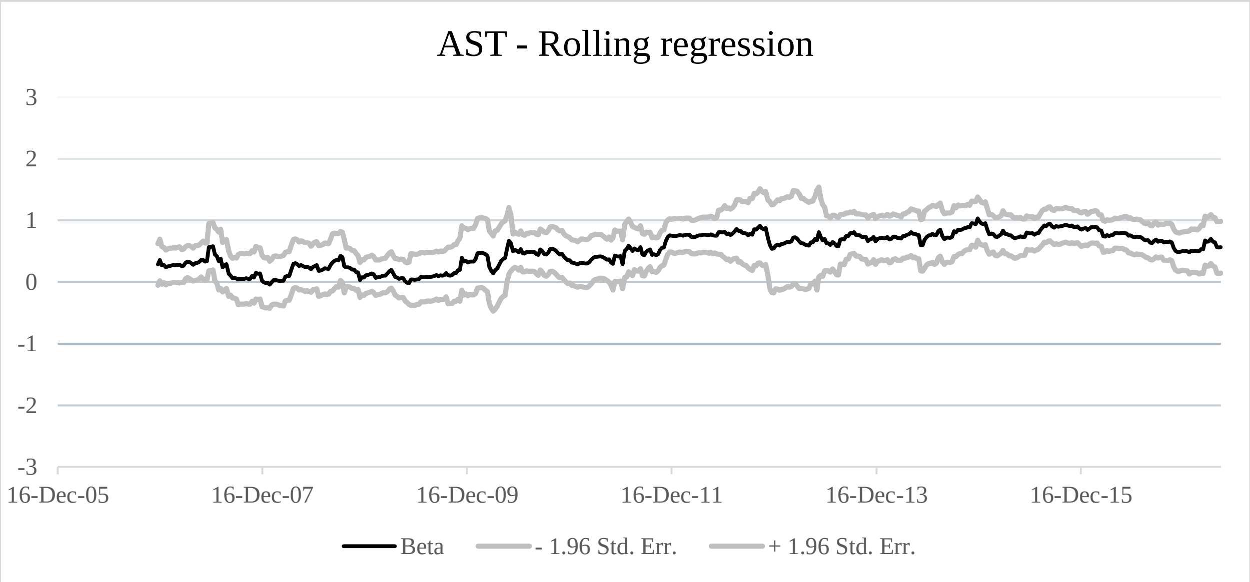


Figure 11: AST 16 Dec 2005 - 28 Apr 2017

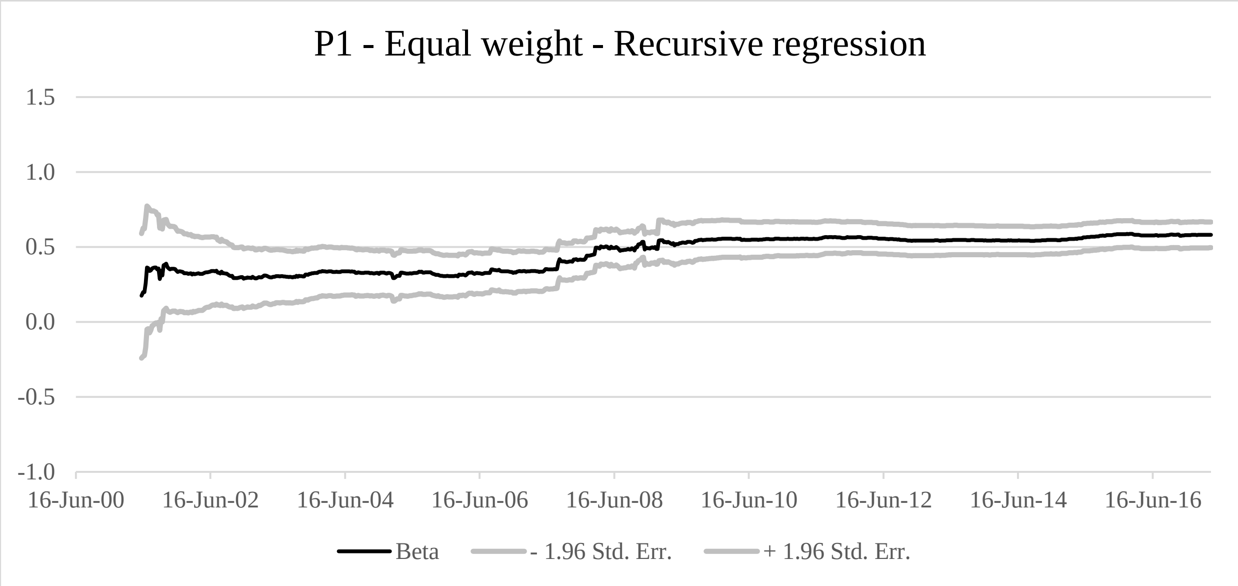




Appendix 2:

Recursive and Rolling Regressions, Portfolios

Figure 12: P1 - Equal Weight



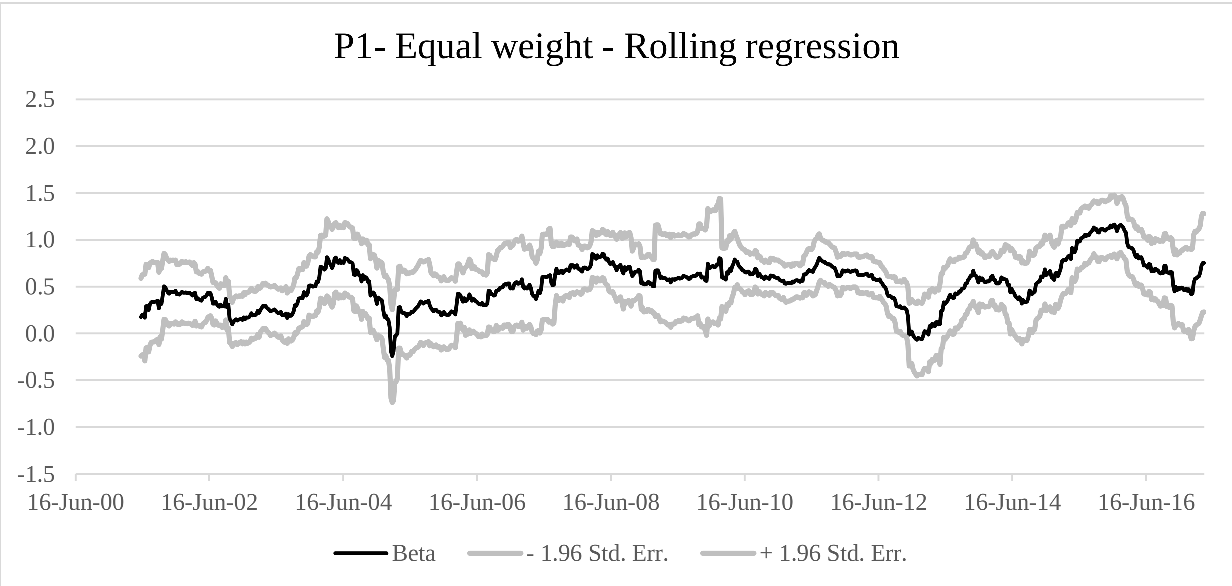
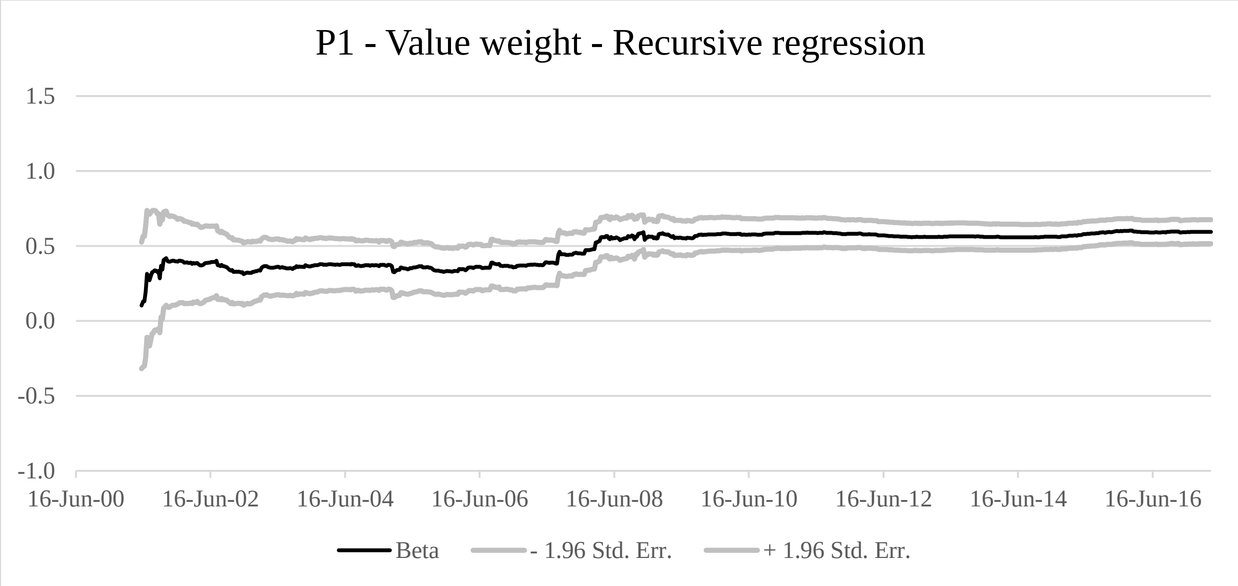


Figure 13: P1 - Value Weight



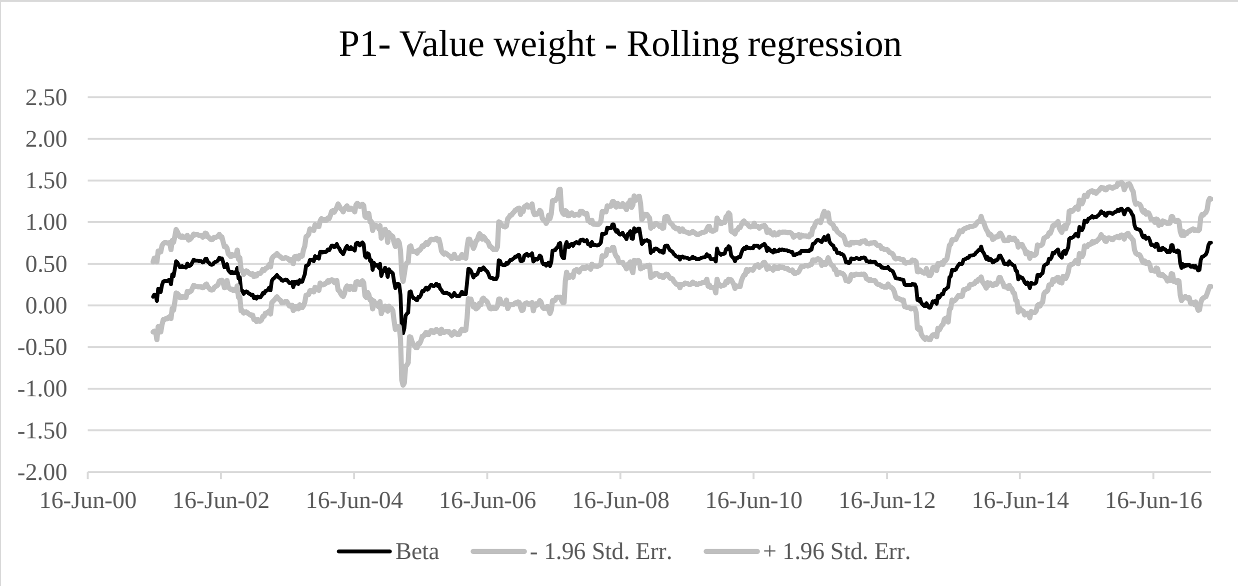
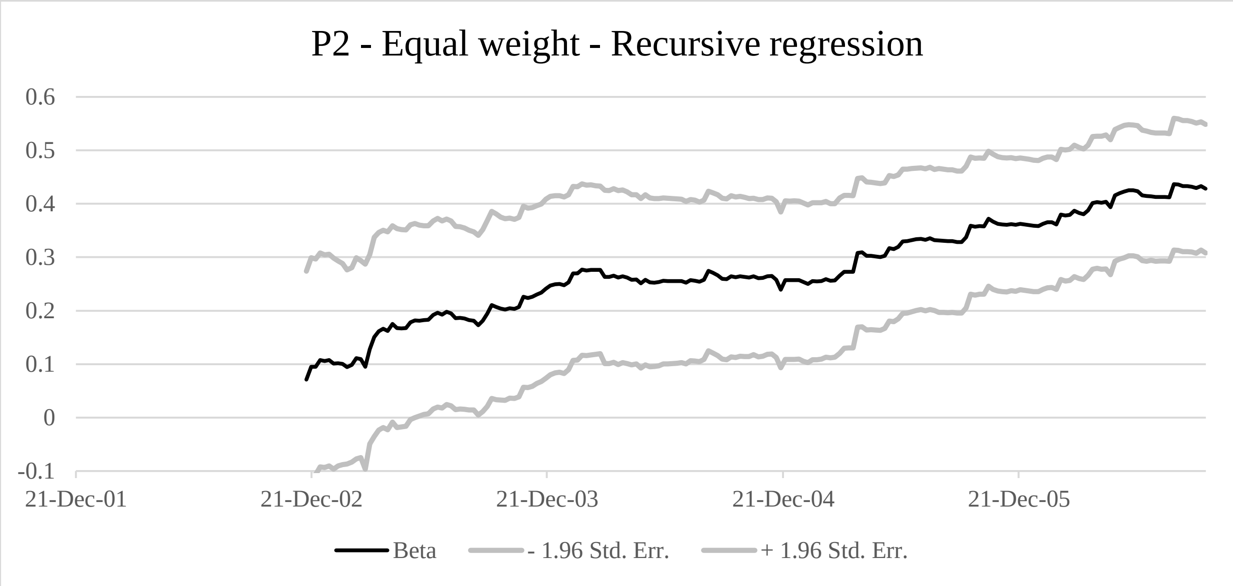


Figure 14: P2 - Equal Weight



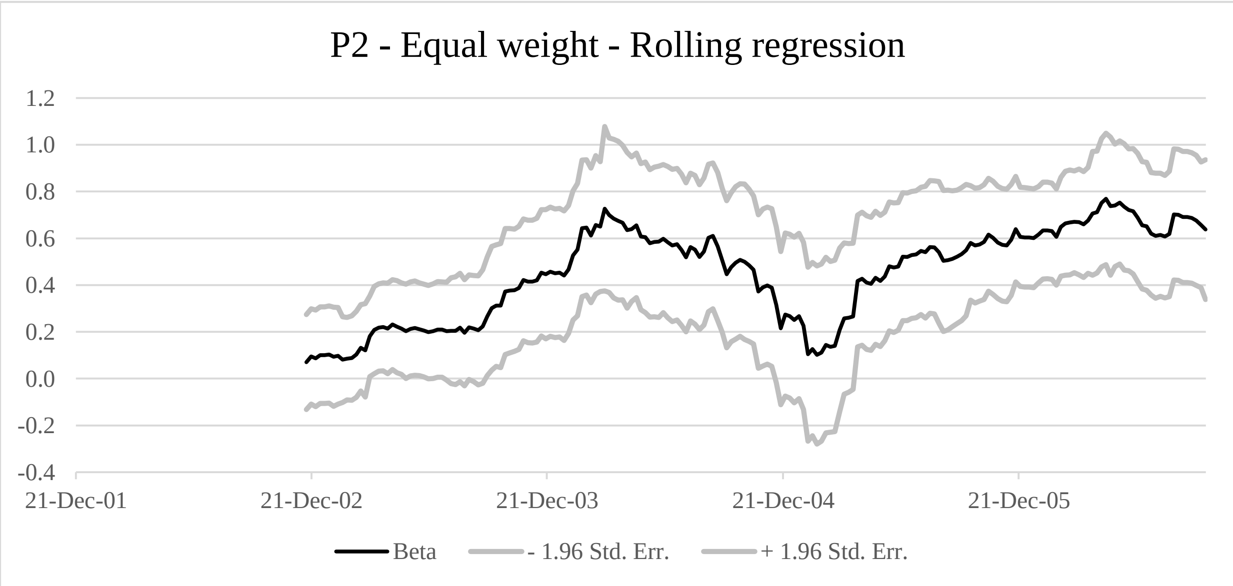
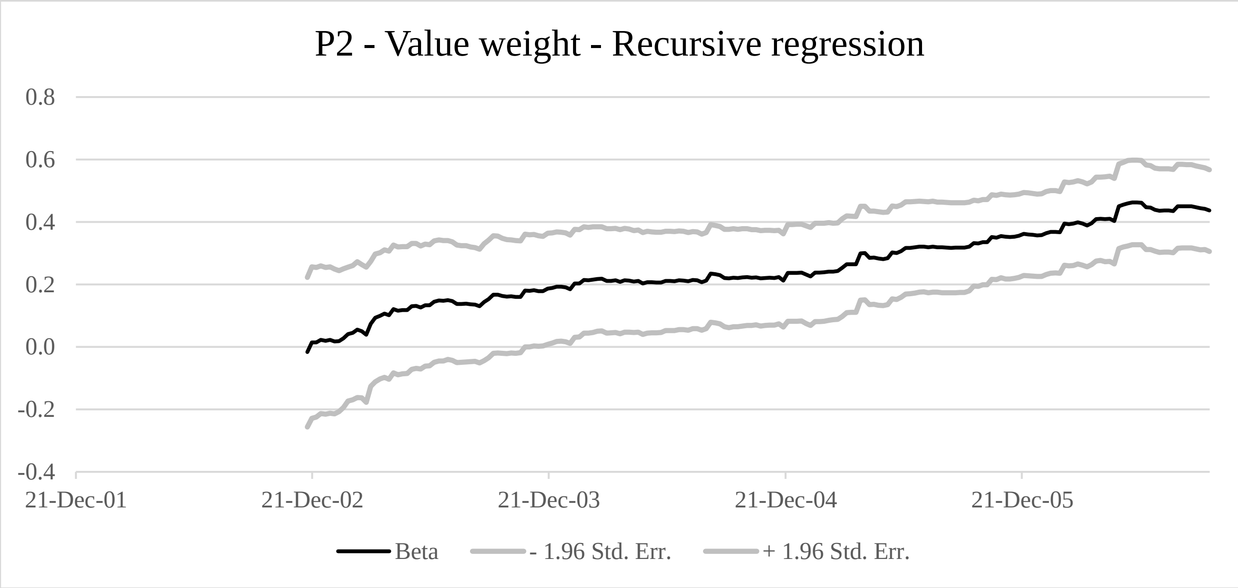


Figure 15: P2 - Value Weight



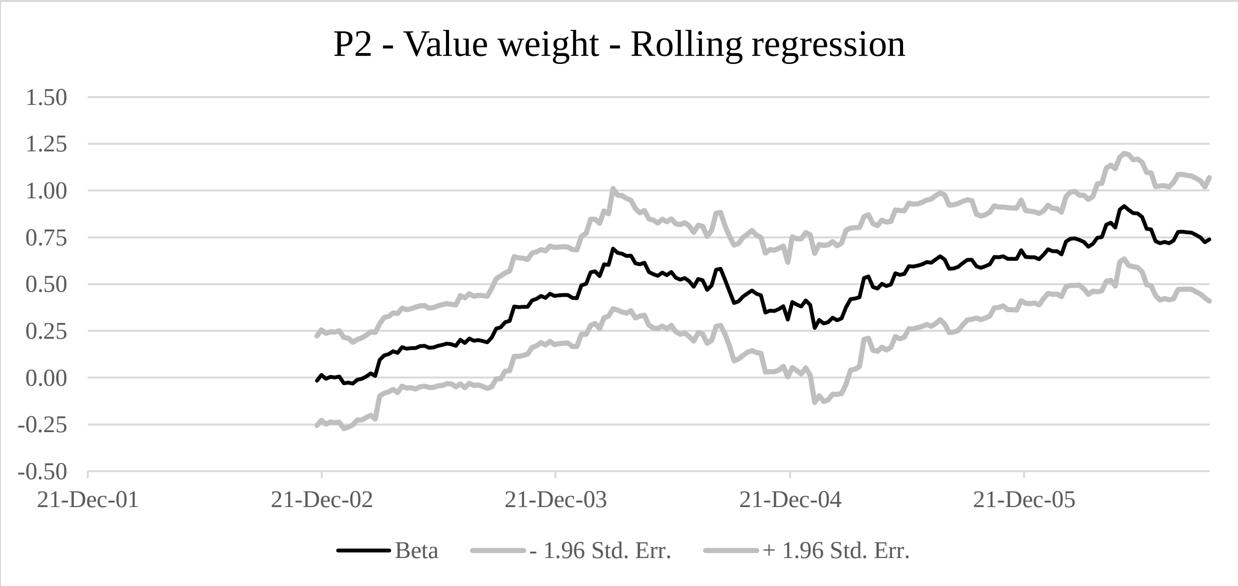
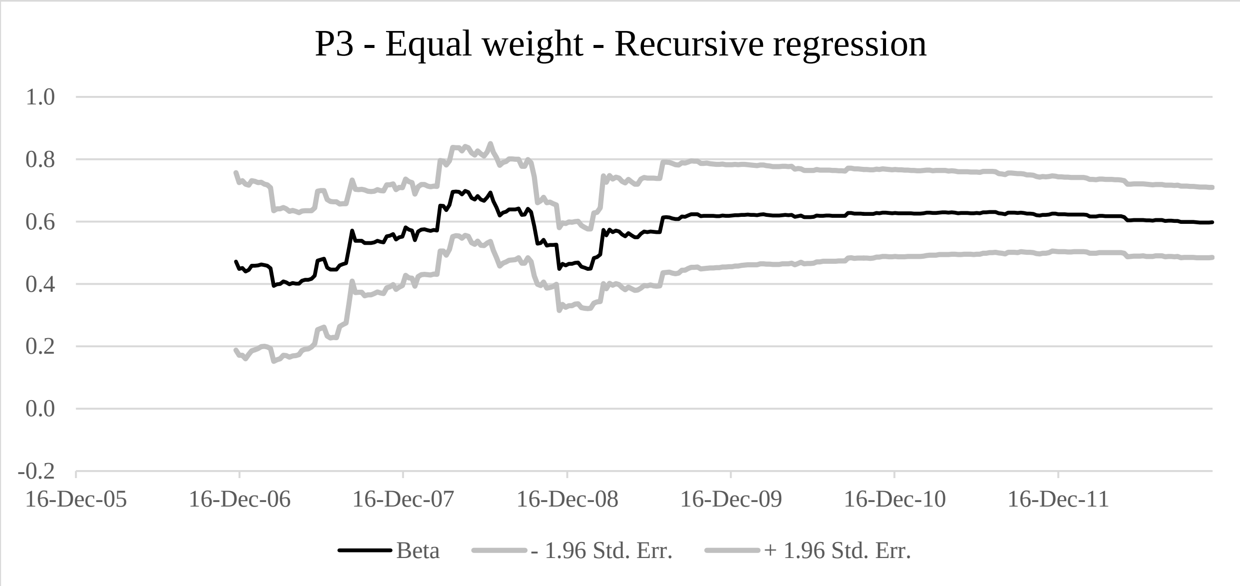


Figure 16: P3 - Equal Weight



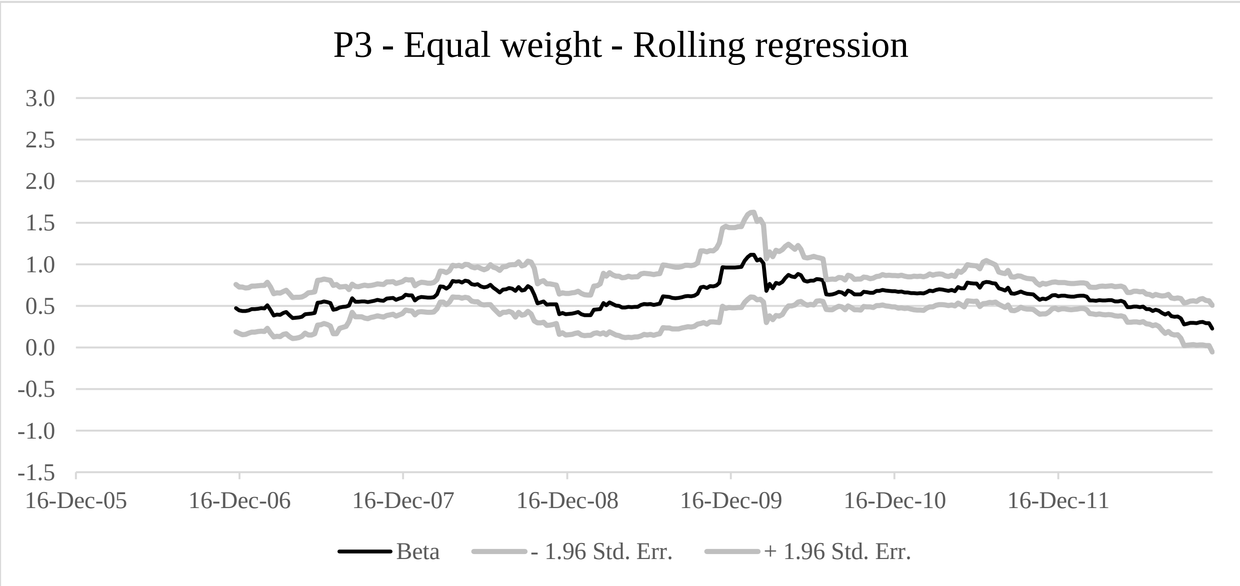
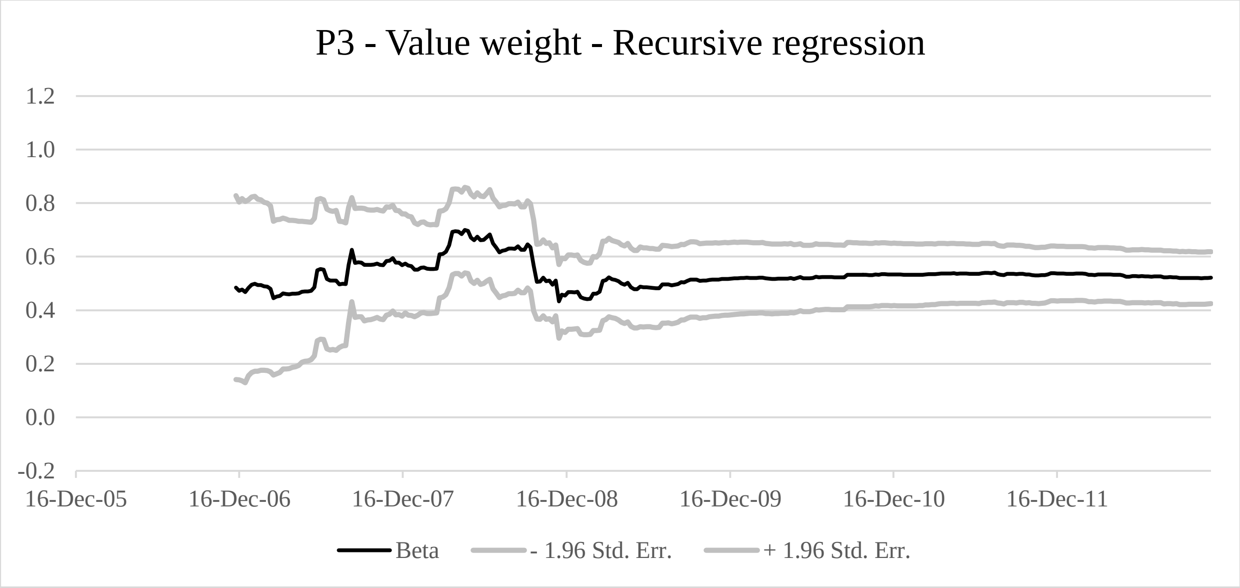


Figure 17: P3 - Value Weight



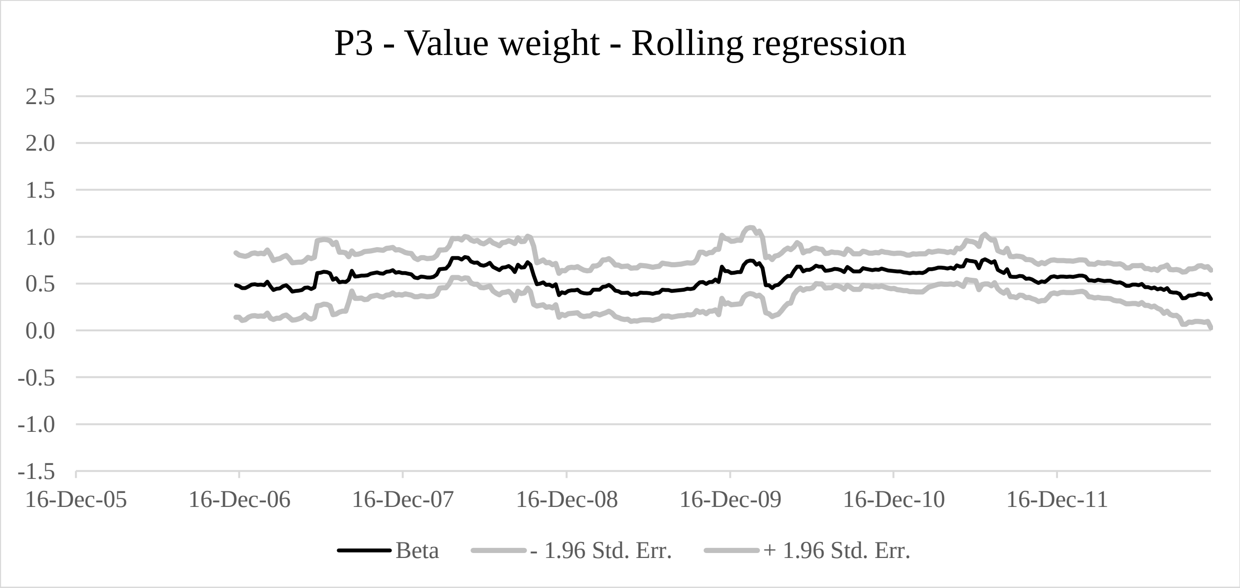
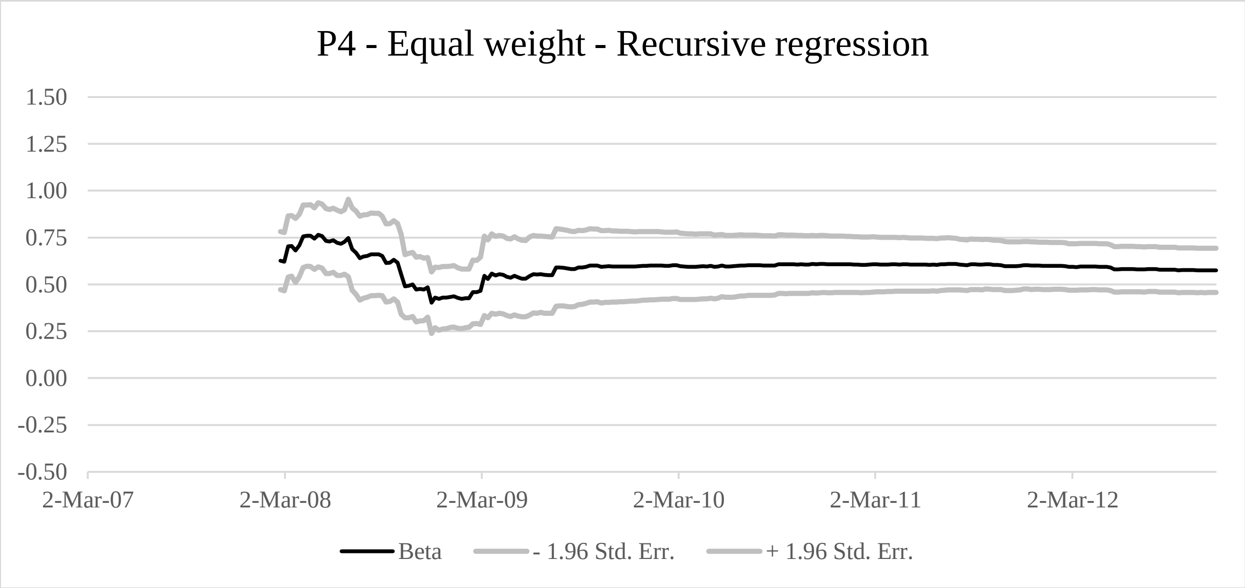


Figure 18: P4 - Equal Weight



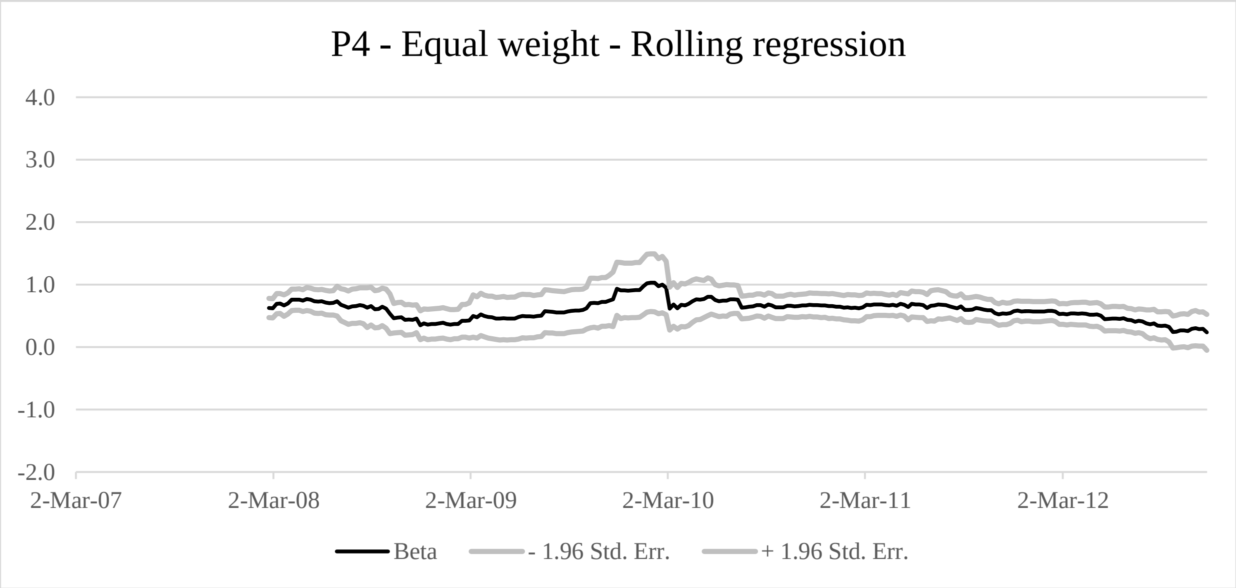
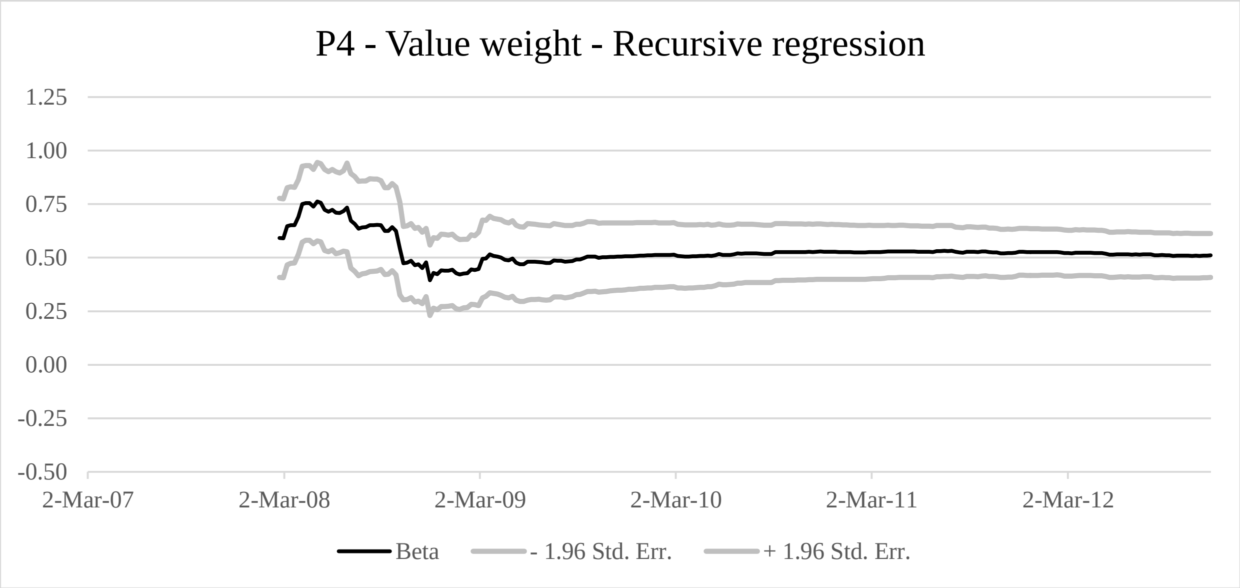


Figure 19: P4 - Value Weight



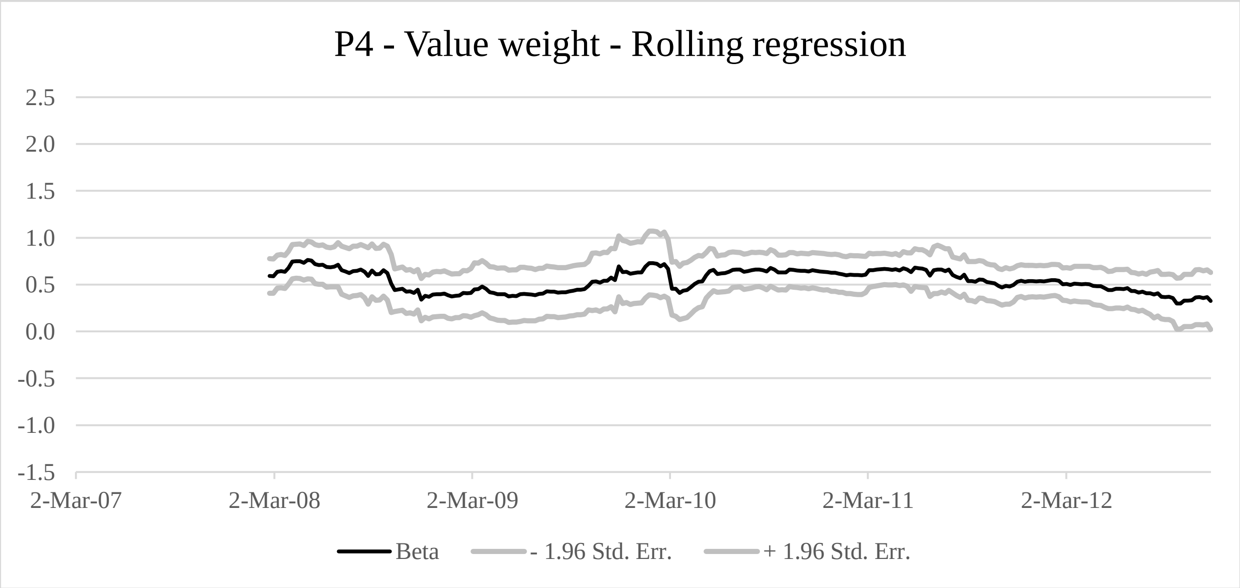
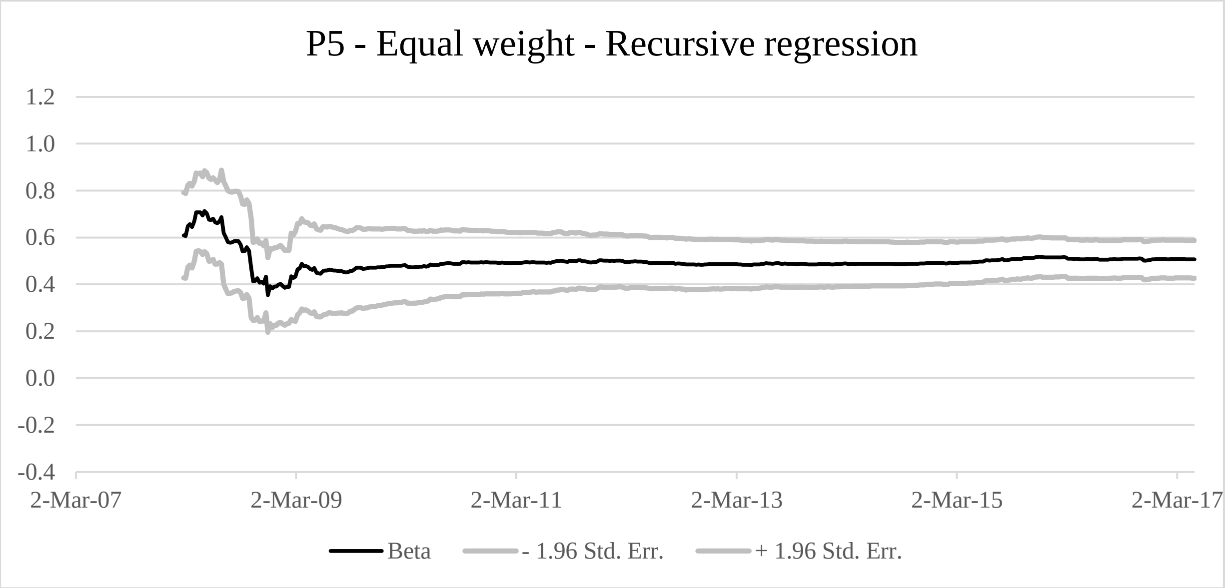


Figure 20: P5 - Equal Weight



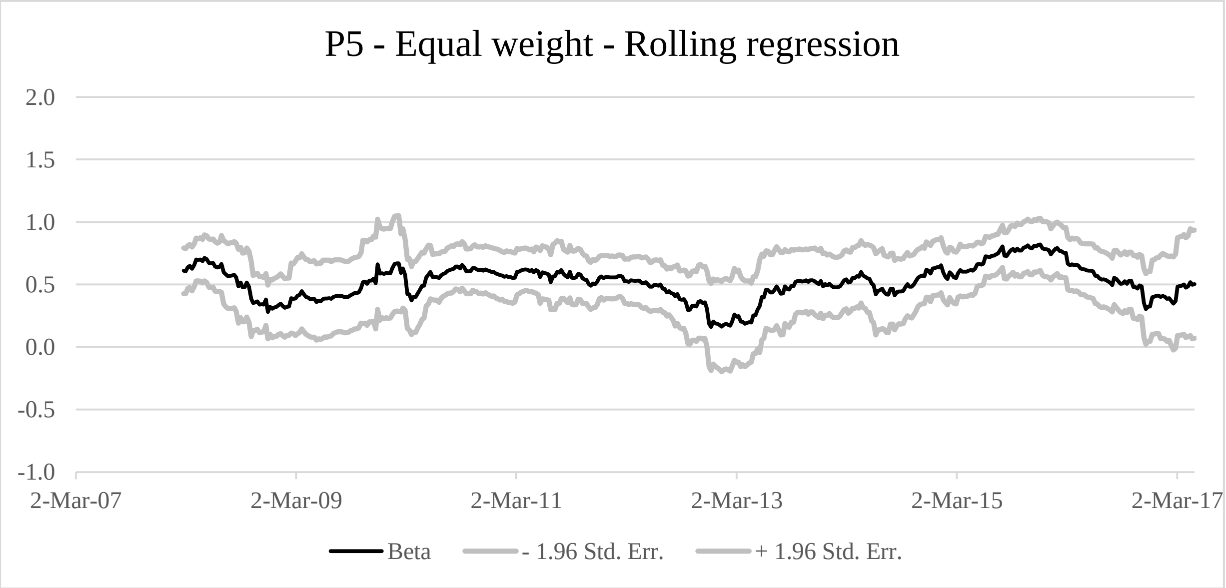
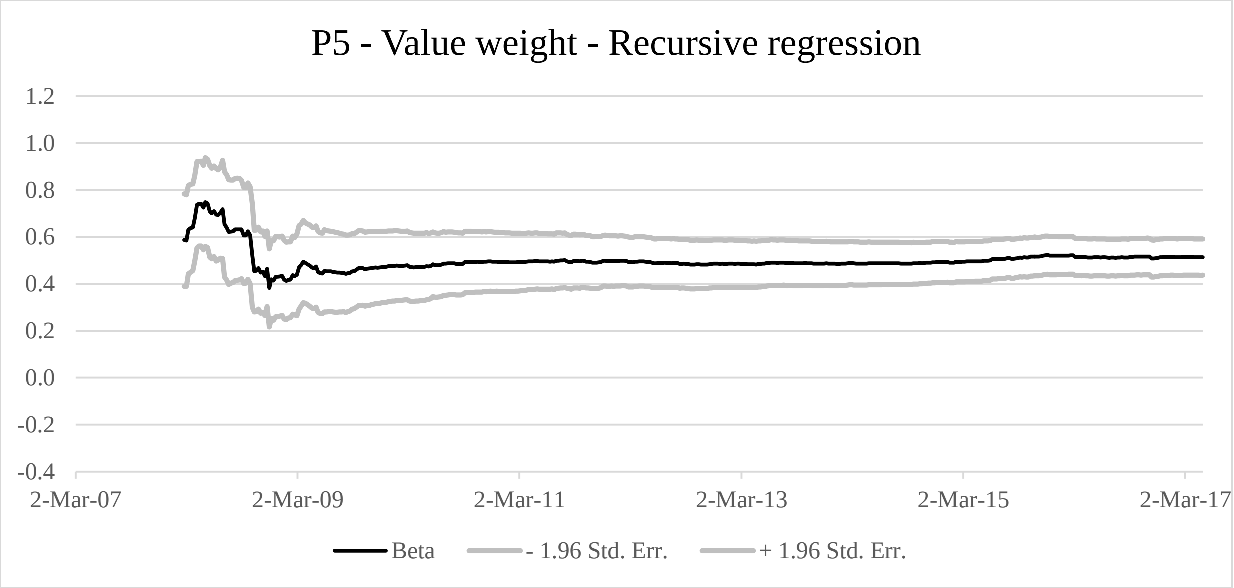


Figure 21: P5 - Value Weight



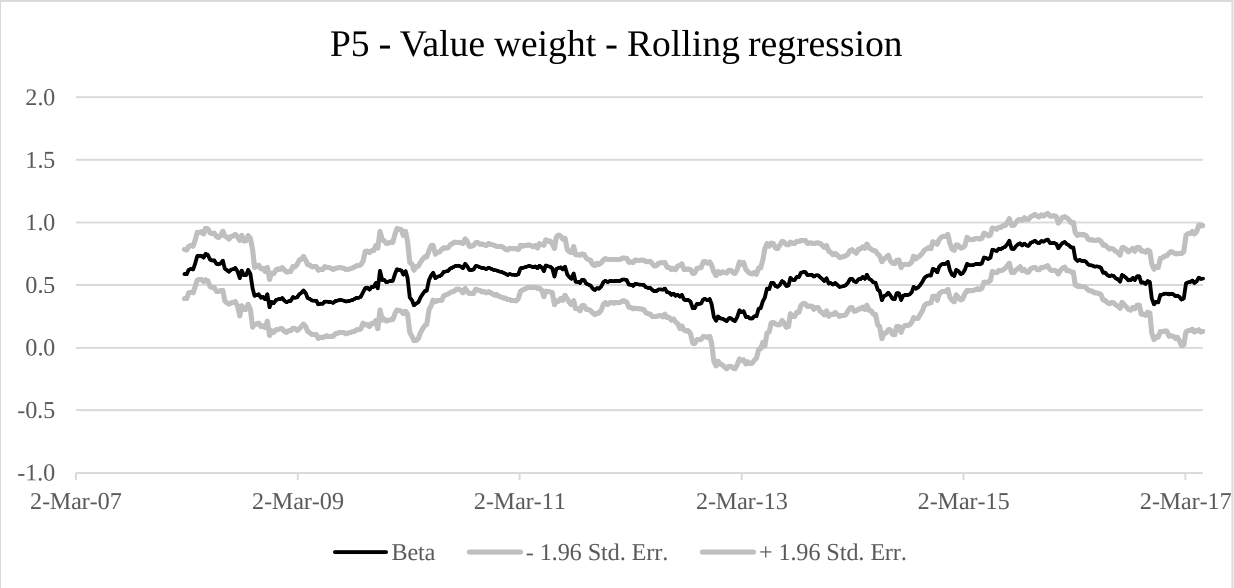
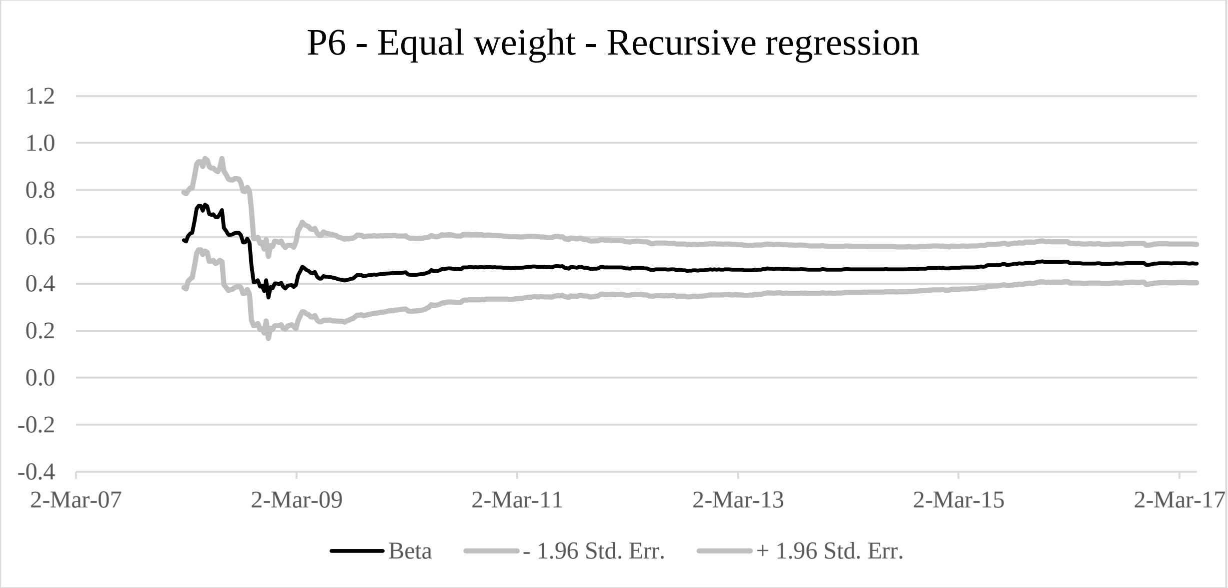


Figure 22: P6 - Equal Weight



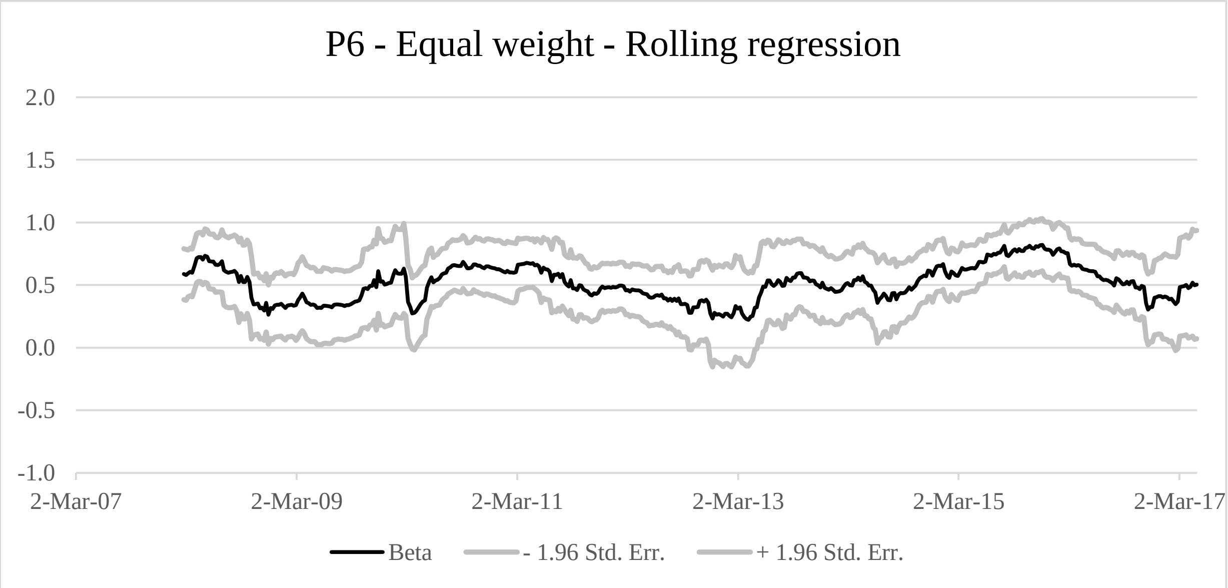
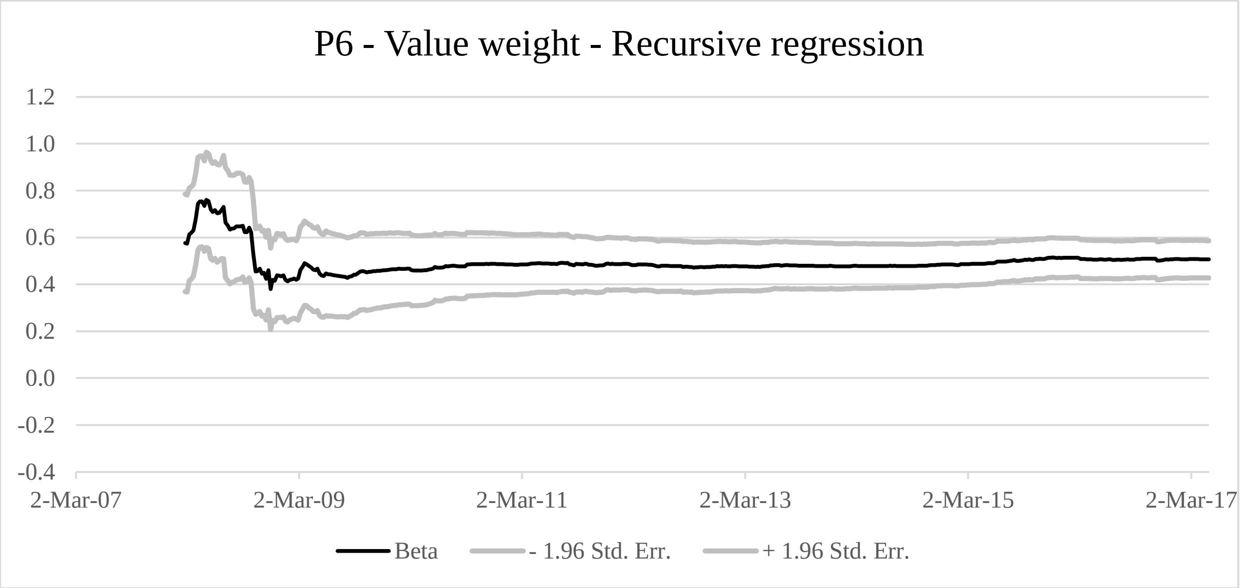
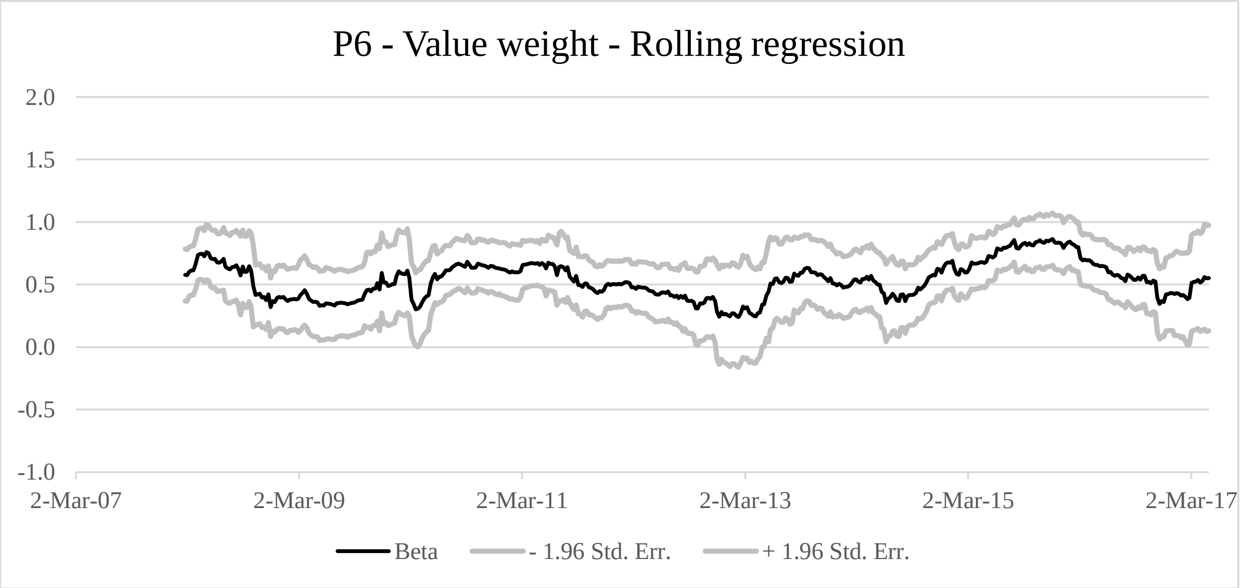


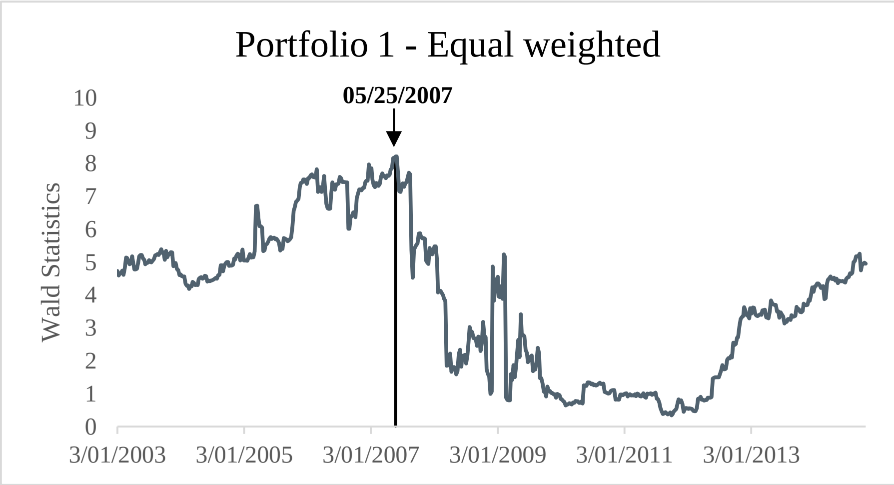
Figure 23: P6 - Value Weight

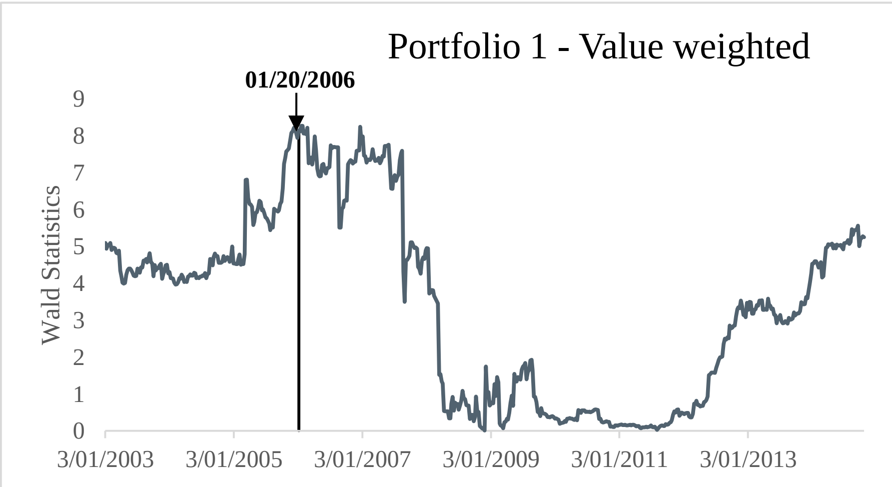


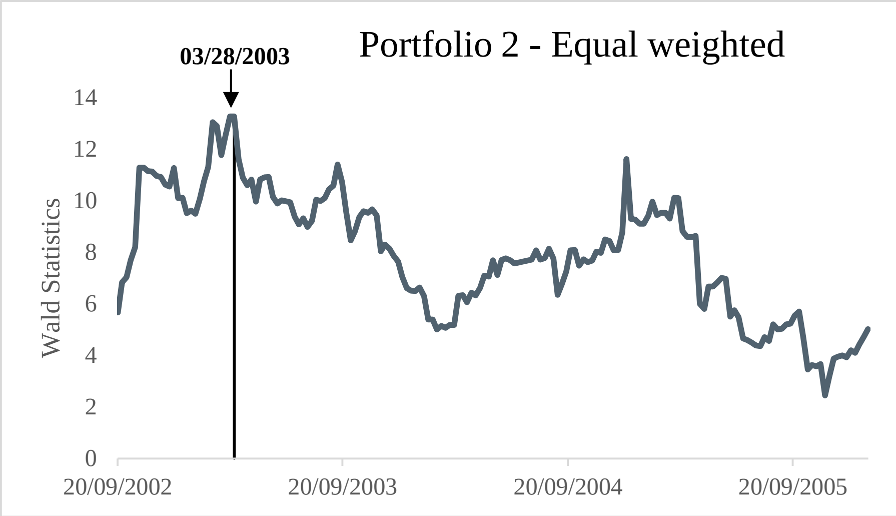


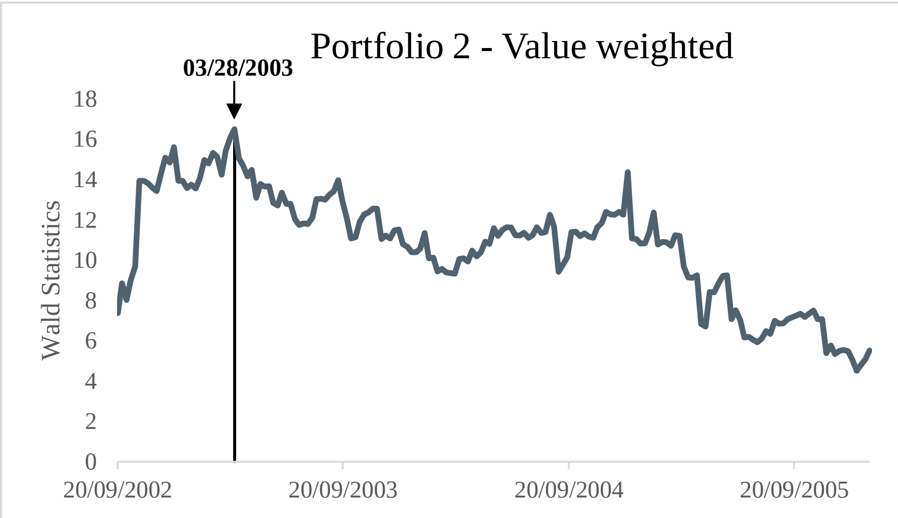
Appendix 3:

Structural Break Test






Portfolio 2 - Equal weighted
03/28/2003
Wald Statistics
14
12
10
8
6
4
2
0
20/09/2002
20/09/2003
20/09/2004
20/09/2005


Portfolio 2 - Value weighted
03/28/2003
Wald Statistics
18
16
14
12
10
8
6
4
2
0
20/09/2002
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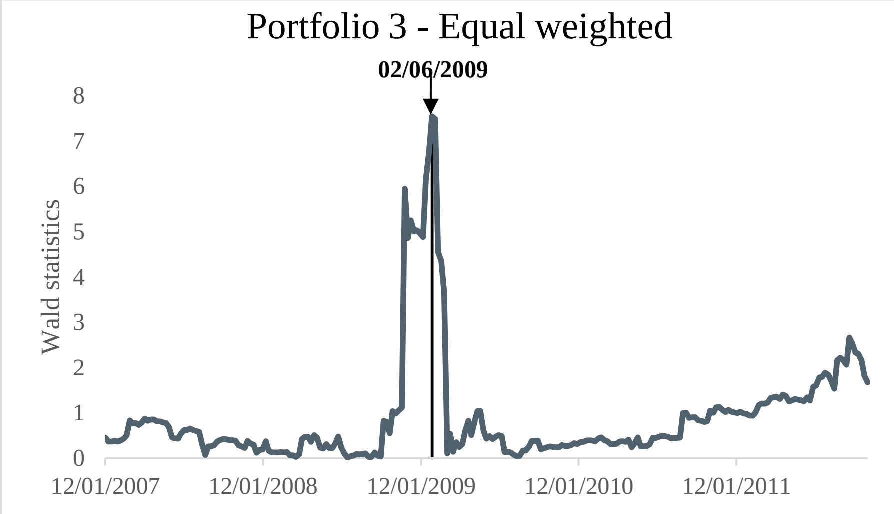
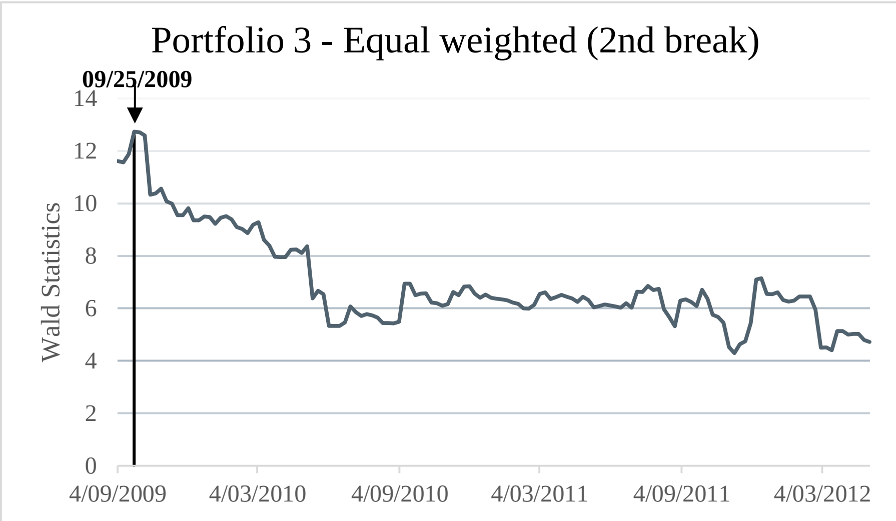
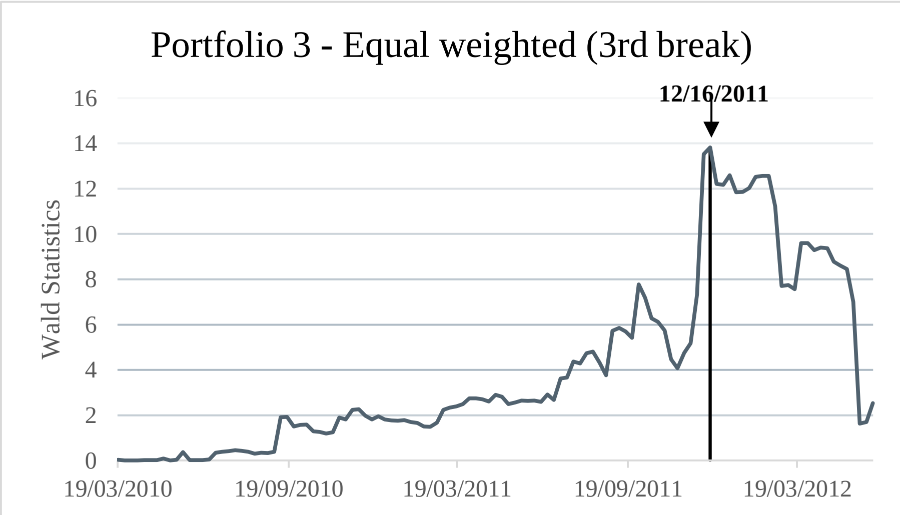
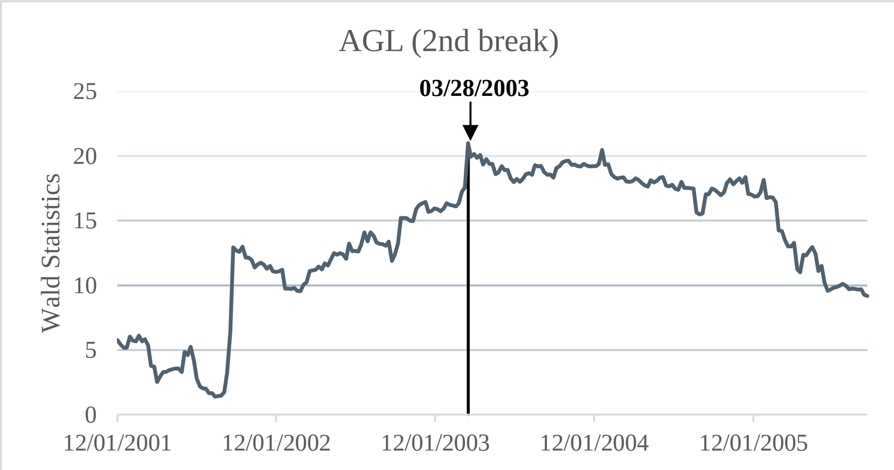
20/09/2004
20/09/2005

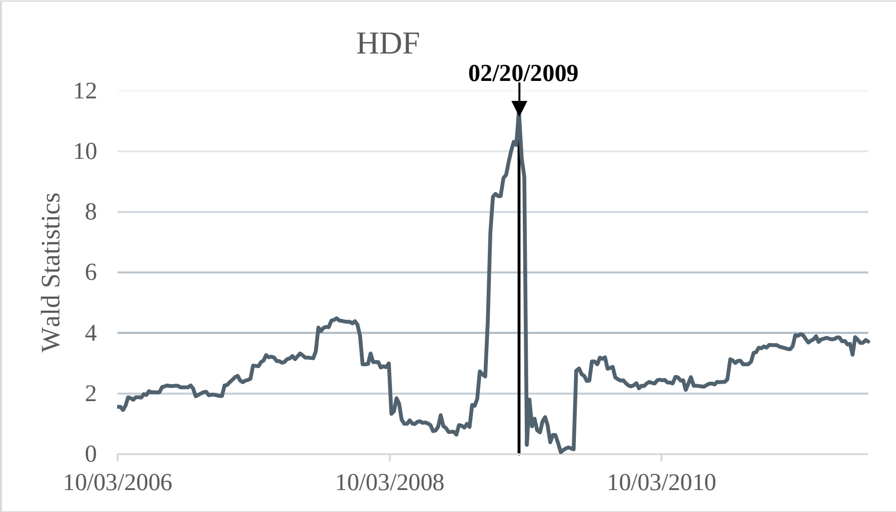

Portfolio 3 - Equal weighted
02/06/2009
Wald statistics
8
7
6
5
4
3
2
1
0
12/01/2007
12/01/2008
12/01/2009
12/01/2010
12/01/2011

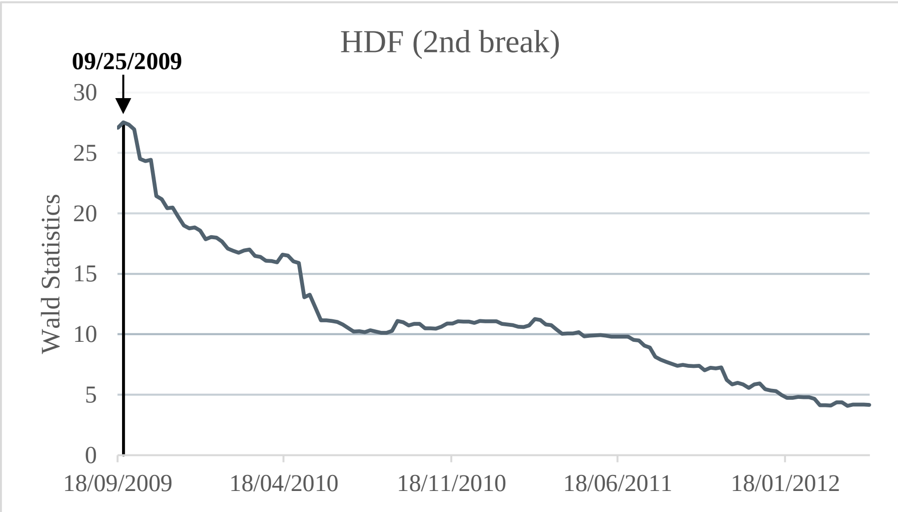

Portfolio 3 - Equal weighted (2nd break)
09/25/2009
Wald Statistics
14
12
10
8
6
4
2
0
4/09/2009
4/03/2010
4/09/2010
4/03/2011
4/09/2011
4/03/2012

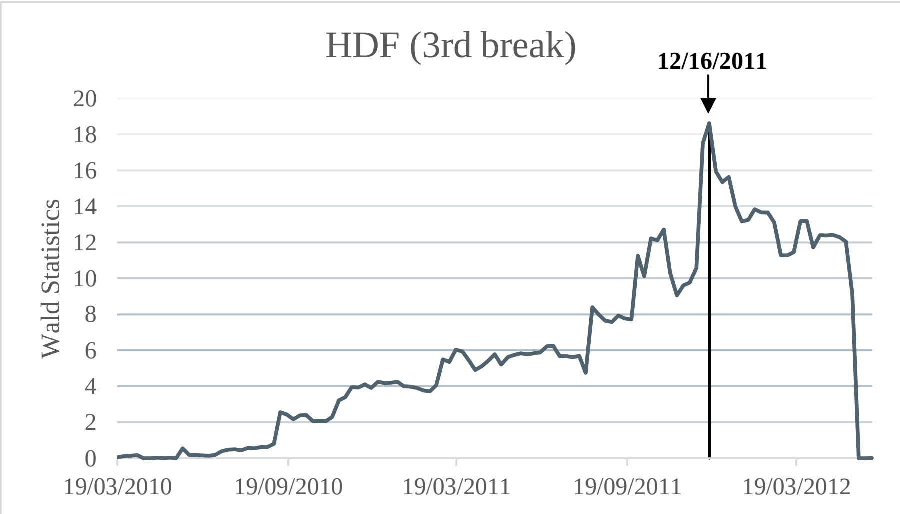

Portfolio 3 - Equal weighted (3rd break)
12/16/2011
Wald Statistics
16
14
12
10
8
6
4
2
0
19/03/2010
19/09/2010
19/03/2011
19/09/2011
19/03/2012

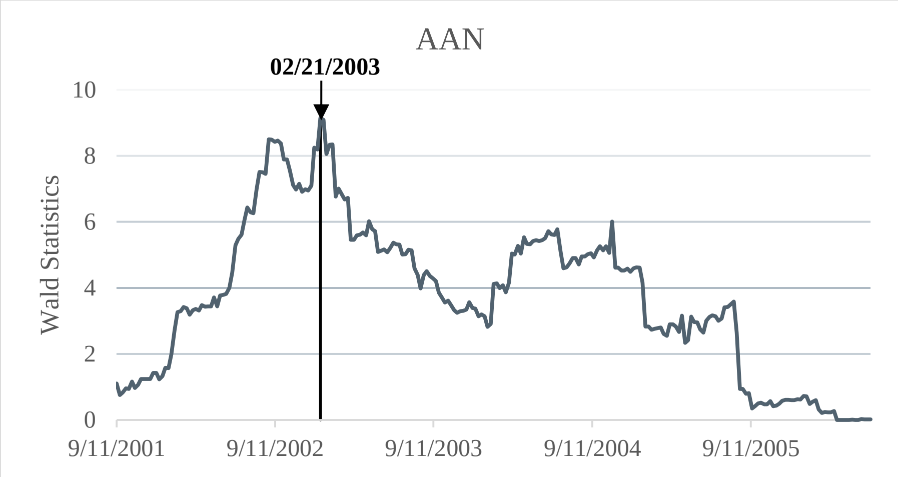

AGL
12/31/1999
Wald Statistics
14
12
10
8
6
4
2
0
5/08/1994
5/08/1997
5/08/2000
5/08/2003


AGL (2nd break)
03/28/2003
Wald Statistics
25
20
15
10
5
0
12/01/2001
12/01/2002
12/01/2003
12/01/2004
12/01/2005


HDF
02/20/2009
12
10
8
6
4
2
0
Wald Statistics
10/03/2006
10/03/2008
10/03/2010


HDF (2nd break)
09/25/2009
30
25
20
15
10
5
0
Wald Statistics
18/09/2009
18/04/2010
18/11/2010
18/06/2011
18/01/2012


HDF (3rd break)
12/16/2011
20
18
16
14
12
10
8
6
4
2
0
Wald Statistics
19/03/2010
19/09/2010
19/03/2011
19/09/2011
19/03/2012


AAN
02/21/2003
Wald Statistics
10
8
6
4
2
0
9/11/2001
9/11/2002
9/11/2003
9/11/2004
9/11/2005


SKI
11/21/2008
Wald Statistics
8
7
6
5
4
3
2
1
0
19/09/2008
19/09/2010
19/09/2012
19/09/2014


AST
05/29/2009
Wald Statistics
30
25
20
15
10
5
0
7/09/2007
7/09/2009
7/09/2011
7/09/2013